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# SCIENTIFIC ASPECTS OF SOME FAMILIAR THINGS.



BY

W. M. WILLIAMS, F.R.S., F.C.S.





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## ON THE SOCIAL BENEFITS OF PARAFFIN.

To the inhabitants of Jupiter, who have always one, two, or three of their four moons in active and efficient radiation, or of Saturn displaying the broad luminous oceans of his mighty rings in addition to the minor lamps of his eight ever-changeful satellites, the relative merits of rushlights, candles, lamps, and gaslights may be a question of indifference; but to us, the residents of a planet which has but one small moon that only displays her nearly full face during a few nights of each month, the subject of artificial light is only second in importance to those of food and artificial heat, and every step that is made in the improvement of our supplies of this primary necessary must have a momentous influence on the physical comfort, and also upon the intellectual and moral progress, of this world's human inhabitants.

If a cockney Rip Van Winkle were to revisit his old haunts, the changes produced by the introduction of gas would probably surprise him the most of all he would see. He would be astonished to find respectable people, and even unprotected females, going alone, unarmed and without fear, at night, up the by-streets which in his days were deemed so dangerous, and he would soon perceive that the bright gaslights had done more than all the laws, the magistrates, and the police, to drive out those crimes which can only flourish in darkness. The intimate connection between physical light and moral and intellectual light and progress is a subject well worthy of an exhaustive treatise.

We must, however, drop the general subject and come down to our particular paraffin lamp. In the first place, this is the cheapest light that has ever been invented—cheaper than any kind of oil lamp—cheaper than the cheapest and nastiest of candles, and, for domestic purposes, cheaper than gas. For large warehouses, shops, streets, public buildings, etc., it is not so cheap as gas should be, but is considerably cheaper than gas actually is at the price extorted by the despotism of commercial monopoly.

The reason why it is especially cheaper for domestic purposes is first, because the small consumer of gas pays a higher price than the large consumer; and secondly, because a lamp can be placed on a table or wherever else its light is required, and therefore a small lamp flame will do the work of a much larger gas flame. We must remember that the intensity of light varies inversely with the square

of the distance from the source of light; thus the amount of light received by this page from a flame at one foot distance is four times as great as if it were two feet distant, nine times as great as at three feet, sixteen times as great as at four feet, one hundred times as great as at ten feet, and so on. Hence the necessity of two or three great flames in a gas chandelier suspended from the ceiling of a moderate-sized room.

In a sitting-room lighted thus with gas, we are obliged, in order to read comfortably by the distant source of light, to burn so much gas that the atmosphere of the room is seriously polluted by the products of this extravagant combustion. A lamp at a moderate distance—say eighteen inches or two feet, or thereabouts—will enable us to read or work with one-tenth to one-twentieth the amount of combustion, and therefore with so much less vitiation of the atmosphere, and, if we use a paraffin lamp, at much less expense.

But the chief value of the paraffin lamp is felt where gas is not obtainable—in the country mansion or villa, the farmhouse, and, most of all, in the poor man's cottage. We have Bible Societies for providing cheap Bibles; we have cheap standard works, cheap magazines, cheap newspapers, etc.; but all these are unavailable to the poor man until he can get a good and cheap light wherewith to read them at the only time he has for reading, viz., in the evenings, when his work is done. One shilling's worth of cheap literature will require two shillings worth of dear candles to supply the light necessary for reading it. Therefore, the cheapening of light has quite as much to do with the poor man's intellectual progress as the cheapening of books and periodicals.

For a man to read comfortably, and his wife to do her needlework, they must have a candle for each, if dependent on tallow dips. They may, and do, struggle on with one such candle, but the inconvenience soon sickens them of their occupation; the man lolls out for an idle stroll, soon encounters a far more bright and cheerful room than the gloomy one he has just left, and, moth-like, he is attracted by the light, and finishes up his evening in the public-house.

We may preach, we may lecture, we may coax, wheedle, or anathematize, but no amount of words of any kind will render a gloomy ill-lighted cottage so attractive as the bright bar and taproom, and human nature, irrespective of conventional distinctions of rank and class, always seeks cheerfulness after a day of monotonous toil. Fifty years ago the middle classes were accustomed to spend their evenings in taverns, but now they prefer their homes, simply because they have learned to make their homes more comfortable and attractive.

We have not yet learned how to supply the working millions with suburban villas, but if their small rooms can be made bright and cheerful during the long evenings, a most important step is made toward that general improvement of social habits which necessarily results from a greater love of home. We may safely venture to predict that the paraffin lamp will have as much influence in elevating the domestic character of the poorer classes as the street lamps have had in purging the streets of our cities from the crimes of darkness that once infested them.

A great deal has been said about the poisonous character of paraffin works. I admit that they have much to answer for in reference to trout—that the clumsy and wasteful management of certain ill-conducted works has interfered with the sport of the anglers of one or two of the trout streams of the United Kingdom—but all the assertions that have been made relative to injury to human health are quite contrary to truth.

The fact is that the manufacture of mineral oils from cannel and shale is an unusually healthful occupation. The men certainly have dirty faces, but are curiously exempt from those diseases which are most fatal among

the poor. I allude to typhus fever, and all that terrible catalogue of ills usually classed under the head of zymotic diseases. This has been strikingly illustrated in the Flintshire district. The very sudden development of the oil trade in the neighborhood of Leeswood caused that little village and the scattered cottages around to be crowded to an extent that created the utmost alarm among all who are familiar with the results of such overcrowding in poor, ill-drained, and ill-ventilated cottages. Rooms were commonly filled with lodgers who economized the apartments on the Box and Cox principle, the night workers sleeping during the day, and the day workers during the night, in the same beds. The extent to which this overcrowding was carried in many instances is hardly credible.

Mr. R. Platt, who is surgeon to most of the collieries and oilworks of this district, reports that Leeswood has enjoyed a singular immunity from typhus and fever—that, during a period when it was prevalent as a serious epidemic among the agricultural population living on the slopes of the surrounding mountains, no single case occurred among the oil-making population of Leeswood, though its position and overcrowding seemed so directly to court its visitation. If space permitted I might give further illustrations in reference to allied diseases.

There is no difficulty in accounting for this. Carbolic acid, one of the most powerful of our disinfectants, is abundantly produced in the oilworks, and this is carried by the clothes of the men, and with the fumes of the oil, into the dwellings of the workmen and through all the atmosphere of the neighborhood, and has thereby counteracted some of the most deadly agencies of organic poisons. Besides this, the paraffin oil itself is a good disinfectant.

Even the mischief done to the trout is more than counterbalanced by the destruction of those mysterious fungoid growths which result from the admixture of sewage matter with the water of our rivers, and are so destructive to human health and life. the carbolic acid and paraffin oil, in destroying these as well as the trout, are really acting as great purifiers of the river, so that, after all, the only interest that has suffered is the sporting interest. This same interest has otherwise suffered. The old haunts of the snipe and woodcock, of partridges, hares, and pheasants, are being ruthlessly and barbarously destroyed, and—horrible to relate—hundreds of cottages, inhabited by vulgar, hard-handed, thick-booted human beings, are taking their place. Churches are being extended, school-houses and chapels built; penny readings, lectures, cencerts, etc., are in active operation, and even drinking fountains are in course of construction; but the trout have suffered, and the woodcocks are gone.

We may thus measure the good against the evil as it stands here in the head-quarters of oil-making, and should add to one side the advantages which the cheap and brilliant light affords—advantages which we might continue to enumerate, but they are so obvious that it is unnecessary to go further.

There is one important and curious matter which must not be omitted. This, like the moral and intellectual advantages of the cheap paraffin light, has hitherto remained unnoticed, viz., that the introduction of mineral oils and solid paraffin for purposes of illumination and lubrication has largely increased the world's supply of food.

This may not be generally obvious at first sight; but to him who, like the writer, has had many a supper at an Italian osteria with peasants and carbonari, it is obvious enough. He will remember how often he has seen the lamp that has lighted himself and companions to their supper filled from the same flask as supplied the salad which formed so important a part of the supper itself. Throughout the South of Europe salads are most important elements of national

food, and when thus abundantly eaten the oil is quite necessary; the oil is also used for many of the cookery operations where butter is used here, and this same olive oil has hitherto been the chief, and in some places the sole, illuminating agent. The poor peasant of the South looks jealously at his lamp, and feeds it stingily, for it consumes his richest and choicest food, and, if well supplied, would eat as much as a fair-sized baby.

The Russian peasant and other Northern people have a similar struggle in the matter of tallow. It is their choicest dainty, and yet, to their bitter grief, they have been compelled to burn it. Hundreds and thousands of tons of this and of olive oil have been annually consumed for the lubrication of our steam engines and other machines. A better time is approaching now that paraffin lamps are so rapidly becoming the chief illuminators of the whole civilized world, superseding the crude tallow candle and the antique olive-oil lamp, while, at the same time, the tallow candle is gradually being replaced by the beautiful sperm-like paraffin candle; and, in addition to this, the greedy engines that have consumed so much of the olive oil and the tallow are learning to be satisfied with lubricators made from minerals kindred to themselves.

The peasants of the sunny South will feed upon salads made doubly unctuous and nutritious by the abundant oil; their fried meats, their pastry, omelettes, and sauces will be so much richer and better than heretofore, and the Russian will enjoy more freely his well-beloved and necessary tallow, when the candle is made and the engine lubricated with the fat extracted from coals and stones which no human stomach can envy. I might travel on to China, and tell of the work that paraffin and paraffin oils have yet to do among the many millions there and in other countries of the East. The great wave of mineral light has not yet fairly broken upon their shores; but when it has once burst through the outer barriers, it will, without doubt, advance with great rapidity, and with an influence whose beneficence can scarcely be exaggerated.

(The above was written in the early days of paraffin lamps, and while the writer was engaged in the distillation of paraffin oils, etc., from the Leeswood cannel. These are now practically superseded by American petroleum of similar composition, but distilled in Nature's oilworks. The anticipations that appeared Utopian at the time of writing have since been fully realized, or even exceeded, as the wholesale price of mineral oil has fallen from two shillings per gallon to an average of about eightpence, and lamps have been greatly improved. At this price the cost of maintaining a light of given power in an ordinary lamp is about equal to that of ordinary London gas, if it were supplied at one shilling per thousand cubic feet. The mineral oil, being a fine hydrocarbon, does far less mischief than gas by its combustion, as may be proved by warming a conservatory with a paraffin stove and another with a gas stove. In the latter all the delicate plants will be killed; in the first they scarcely suffer at all. If these facts were generally understood we should be in a better position for battle with the gas monopolies. The importation of petroleum to the United Kingdom during the first five months of 1882 amounted to 26,297,346 gallons.)

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## THE FORMATION OF COAL.

In the course of a pedestrian excursion made in the summer of 1855 I came upon the Aachensee, one of the lakes of North Tyrol rarely visited by tourists. It is situated about 30 miles N.E. of Innspruck, and fills the basin of a deep valley, the upper slopes of which are steep and richly wooded. The water of this lake is

remarkably transparent and colorless. With one exception, that of the Fountain of Cyane—a deep pool forming the source of the little Syracusan river—it is the most transparent body of water I remember to have seen. This transparency revealed a very remarkable sub-aqueous landscape. The bottom of the lake is strewn with branches and trunks of trees, which in some parts are in almost forest-like profusion. As I was alone in a rather solitary region, and carrying only a satchel of luggage, my only means of further exploration were those afforded by swimming and diving. Being an expert in these, and the July summer day very calm and hot, I remained a long time in the water, and, by swimming very carefully to avoid ripples, was able to survey a considerable area of the interesting scene below.

The fact which struck me the most forcibly, and at first appeared surprising, was the upright position of many of the large trunks, which are of various lengths—some altogether stripped of branches, others with only a few of the larger branches remaining. The roots of all these are more or less buried, and they present the appearance of having grown where they stand. Other trunks were leaning at various angles and partly buried, some trunks and many branches lying down.

On diving I found the bottom to consist of a loamy powder of gray color, speckled with black particles of vegetable matter—thin scaly fragments of bark and leaves. I brought up several twigs and small branches, and with considerable difficulty, after a succession of immersions, succeeded in raising a branch about as thick as my arm and about eight feet long, above three-fourths of which was buried, and only the end above ground in the water. My object was to examine the condition of the buried and immersed wood, and I selected this as the oldest piece I could reach.

I found the wood very dark, the bark entirely gone, and the annual layers curiously loosened and separable from each other, like successive rings of bark. This continued till I had stripped the stick to about half of its original thickness, when it became too compact to yield to further stripping.

This structure apparently results from the easy decomposition of the remains of the original cambium of each year, and may explain the curious fact that so many specimens of fossilized wood exhibit the original structure of the stem, although all the vegetable matter has been displaced by mineral substances. If this stem had been immersed in water capable of precipitating or depositing mineral matter in very small interstices, the deposit would have filled up the vacant spaces between these rings of wood as the slow decomposition of the vegetable matter proceeded. At a later period, as the more compact wood became decomposed, it would be substituted by a further deposit, and thus concentric strata would be formed, presenting a mimic counterpart of the vegetable structure.

The stick examined appeared to be a branch of oak, and was so fully saturated with water that it sunk rapidly upon being released.

On looking around the origin of this sub-aqueous forest was obvious enough. Here and there the steep wooded slopes above the lake were broken by long alleys or downward strips of denuded ground, where storm torrents, or some such agency, had cleared away the trees and swept most of them into the lake. A few uprooted trees lying at the sides of these bare alleys told the story plainly enough. Most of these had a considerable quantity of earth and stones adhering to their roots: this explains the upright position of the trees in the lake.

Such trees falling into water of sufficient depth to enable them to turn over must sink root downward, or float in an upright position, according to the quantity of adhering soil. The difference of depth would tend to a

more rapid penetration of water in the lower parts, where the pressure would be greatest, and thus the upright or oblique position of many of the floating trunks would be maintained till they absorbed sufficient water to sink altogether.

It is generally assumed that fossil trees which are found in an upright position have grown on the spot where they are found. The facts I have stated show that this inference is by no means necessary, not even when the roots are attached and some soil is found among them. In order to account for the other surroundings of these fossil trees a very violent hypothesis is commonly made, viz., that the soil on which they grew sunk down some hundreds of feet without disturbing them. This demands a great strain upon the scientific imagination, even in reference to the few cases where the trees stand perpendicular. As the majority slope considerably the difficulty is still greater. I shall presently show how trees like those immersed in Aachensee may have become, and are now becoming, imbedded in rocks similar to those of the Coal Measures.

In the course of subsequent excursions on the fjords of Norway I was reminded of the sub-aqueous forest of the Aachensee, and of the paper which I read at the British Association meeting of 1865, of which the above is an abstract—not by again seeing such a deposit under water, for none of the fjords approach the singular transparency of the lake, but by a repetition on a far larger scale of the downward strips of denuded forest-ground. Here, in Norway, their magnitude justifies me in describing them as vegetable avalanches. They may be seen on the Sognefjord, and especially on those terminal branches of this great estuary, of which the steep slopes are well wooded. But the most remarkable display that I have seen was in the course of the magnificent, and now easily made, journey up the Storfjord, and its extension and branches, the Slyngsfjord, Sunelvsfjord, Nordalsfjord, and Geirangerfjord. Here these avalanches of trees, with their accompaniment of fragments of rock, are of such frequent occurrence that sites of the farmhouses are commonly selected with reference to possible shelter from their ravages. In spite of this they do not always escape. In the October previous to my last visit a boathouse and boat were swept away; and one of the most recent among the tracks that I saw reached within twenty yards of some farm-buildings.

What has become of the millions of trees that are thus falling, and have fallen, into the Norwegian fjords during the whole of the present geological era? In considering this question we must remember that the mountain slopes forming the banks of these fjords continue downward under the waters of the fjords which reach to depths that in some parts are to be counted in thousands of feet.

It is evident that the loose stony and earthy matter that accompanies the trees will speedily sink to the bottom and rest at the foot of the slope somewhat like an ordinary sub-aërial talus, but not so the trees. The impetus of their fall must launch them afloat and impel them toward the middle of the estuary, where they will be spread about and continue floating, until by saturation they become dense enough to sink. They will thus be pretty evenly distributed over the bottom. At the middle part of the estuary they will form an almost purely vegetable deposit, mingled only with the very small portion of mineral matter that is held in suspension in the apparently clear water. This mineral matter must be distributed among the vegetable matter in the form of impalpable particles having a chemical composition similar to that of the rocks around. Near the shores a compound deposit must be formed consisting of trees and fragments of leaves, twigs, and other vegetable matter mixed with larger proportions of the mineral *débris*.

If we look a little further at what

is taking place in the fjords of Norway we shall see how this vegetable deposit will be succeeded by an overlying mineral deposit which must ultimately constitute a stratified rock.

All these fjords branch up into inland valleys down which pours a brawling torrent or a river of some magnitude. These are more or less turbid with glacier mud or other detritus, and great deposits of this material have already accumulated in such quantity as to constitute characteristic modern geological formations bearing the specific Norsk name of *ören*, as *Laerdalsören*, *Sundalsören*, etc., describing the small delta plains at the mouth of a river where it enters the termination of the fjord, and which, from their exceptional fertility, constitute small agricultural settlements bearing these names, which signify the river sands of *Laerdal*, *Sundal*, etc. These deposits stretch out into the fjord, forming extensive shallows that are steadily growing and advancing further and further into the fjord. One of the most remarkable examples of such deposits is that brought by the Storelv (or Justedals Elv), which flows down the Justedal, receiving the outpour from its glaciers, and terminates at Marifjören. When bathing here I found an extensive sub-aqueous plain stretching fairly across that branch of the Lyster fjord into which the Storelv flows. The waters of the fjord are whitened to a distance of two or three miles beyond the mouth of the river. These deposits must, if the present conditions last long enough finally extend to the body, and even to the mouth of the fjords, and thus cover the whole of the bottom vegetable bed with a stratified rock in which will be entombed, and well preserved, isolated specimens of the trees and other vegetable forms corresponding to those accumulated in a thick bed below, but which have been lying so long in the clear waters that they have become soddened into homogeneous vegetable pulp or mud, only requiring the pressure of solid superstratum to convert them into coal.

The specimens of trees in the upper rock, I need scarcely add, would be derived from the same drifting as that which produced the lower pulp; but these coming into the water at the period of its turbidity and of the rapid deposition of mineral matter, would be sealed up one by one as the mineral particles surrounding it subsided. Fossils of estuarine animals would, of course, accompany these, or of fresh-water animals where, instead of a fjord, the scene of these proceedings is an inland lake. In reference to this I may state that at the inner extremities of the larger Norwegian fjords the salinity of the water is so slight that it is imperceptible to taste. I have freely quenched my thirst with the water of the Sörfjord, the great inner branch of the Hardanger, where pallid specimens of bladder wrack were growing on its banks.

In the foregoing matter-of-fact picture of what is proceeding on a small scale in the Aachensee, and on a larger in Norway, we have, I think, a natural history of the formation, not only of coal seams, but also of the Coal Measures around and above them.

The theory which attributed our coal seams to such vegetable accumulations as the rafts of the Mississippi is now generally abandoned. It fails to account for the state of preservation and the position of many of the vegetable remains associated with coal.

There is another serious objection to this theory that I have not seen expressed. It is this:—Rivers bringing down to their mouths such vegetable deltas as are supposed, would also bring considerable quantities of earthy matter in suspension, and this would be deposited with the trees. Instead of the 2 or 3 per cent. of incombustible ash commonly found in coal, we should thus have a quantity more nearly like that found in bituminous shales which may thus be formed, viz. from twenty to eighty per cent.

The alternative hypothesis now

more commonly accepted—that the vegetation of our coal fields actually grew where we find it—is also refuted by the composition of coal-ash. If the coal consisted simply of the vegetable matter of buried forests its composition should correspond to that of the ashes of plants; and the refuse from our furnaces and fire-places would be a most valuable manure. This we know is not the case. Ordinary coal-ash, as Bischof has shown, nearly corresponds to that of the rocks with which it is associated; and he says that "the conversion of vegetable substances into coal has been effected by the agency of water;" and also that coal has been formed, not from dwarfish mosses, sedges, and other plants which now contribute to the growth of our peat-bogs, but from the stems and trunks of the forest trees of the Carboniferous Period, such as *Sigillariæ Lepidodendra*, and *Coniferæ*.* All we know of these plants teaches us that they could not grow in a merely vegetable soil containing but 2 or 3 per cent. of mineral matter. Such must have been their soil for hundreds of generations in order to give a depth sufficient for the formation of the South Staffordshire 10 yard seam.

All these and other difficulties that have stood so long in the way of a satisfactory explanation of the origin of coal appear to me to be removed if we suppose that during the Carboniferous Period Britain and other coal-bearing countries had a configuration similar to that which now exists in Norway, viz., inland valleys terminating in marine estuaries, together with inland lake basins. If to this we superadd the warm and humid climate usually attributed to the Carboniferous Period, on the testimony of its vegetable fossils, all the conditions requisite for producing the characteristic deposits of the Coal Measures are fulfilled.

We have first the under-clay due to the beginning of this state of things, during which the hill slopes were slowly acquiring the first germs of subsequent forest life, and were nursing them in their scanty youth. This deposit would be a mineral mud with a few fossils and that fragmentary or fine deposit of vegetable matter that darkens the carboniferous shales and stripes the sandstones. Such a bed of dark consolidated mud, or fine clay, is found under every seam of coal, and constitutes the "floor" of the coal pit. The characteristic striped rocks —the "linstey" or "linsey" of the Welsh colliers—is just such as I found in the course of formation in the Aachensee near the shore, as described above.

The prevalence of estuarine and lacustrine fossils in the Coal Measures is also in accordance with this: the constitution of coal-ash is perfectly so. Its extreme softness and fineness of structure; its chemical resemblance to the rocks around, and above, and below; the oblong basin form common to our coal seams; the apparent contradiction of such total destruction of vegetable structure common to the true coal seams, while immediately above and below them are delicate structures well preserved, is explained by the more rapid deposition of the latter, and the slow soddening of the former as above described.

I do not, however, offer this as an explanation of the formation of *every kind of coal*. On the contrary, I am satisfied that cannel coal, and the black shales usually associated with it, have a different origin from that of the ordinary varieties of bituminous coal. The fact that the products of distillation of cannel and these shales form different series of hydrocarbons from those of common coal, and that they are nearly identical with those obtained by the distillation of peat, is suggestive of origin in peat-bogs, or something analogous to them.

To the above I may add the concluding sentences of the chapter on coal in Lyell's "Elements of Geology." Speaking of fossils in the Coal Meas-

* Hull, *On the coal-fields of Great Britain.*

ures, he says: "The rarity of air-breathers is a very remarkable fact when we reflect that our opportunities of examining strata *in close connection with ancient land* exceed in this case all that we enjoy in regard to any other formations, whether primary, secondary, or tertiary. We have ransacked hundreds of soils replete with the fossil roots of trees, have dug out hundreds of erect trunks and stumps which stood in the position in which they grew, have broken up myriads of cubic feet of fuel still retaining its vegetable structure, and, after all, we continue almost as much in the dark respecting the invertebrate air-breathers of this epoch, *as if the coal had been thrown down in mid-ocean.* The early date of the carboniferous strata cannot explain the enigma, because we know that while the land supported a luxuriant vegetation, the contemporaneous seas swarmed with life—with Articulata, Mollusca, Radiata, and Fishes. We must, therefore, collect more facts if we expect to solve a problem which, in the present state of science, cannot but excite our wonder; and we must remember how much the conditions of this problem have varied within the last twenty years. We must be content to impute the scantiness of our data and our present perplexity partly to our want of diligence as collectors, and partly to our want of skill as interpreters. We must also confess that our ignorance is great of the laws which govern the fossilization of land animals, whether of low or high degree."

The explanation of the origin of coal which I have given in the foregoing meets all these difficulties. It shows how vast accumulations of vegetable matter may have been formed "in close connection with the ancient land," and yet "as if the coal had been thrown down in mid-ocean" as far as the remains of terrestrial animals are concerned. It explains the nearly total absence of land shells, and of the remains of other animals that must have lived in the forests producing the coal, and which would have been buried there with the coal had it been formed on land as usually supposed. It also meets the cases of the rare and curious exceptions, seeing that occasionally a land animal would here and there be drowned in such fjords under circumstances favorable to its fossilization.

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## THE CHEMISTRY OF BOG RECLAMATION.

THE mode of proceeding for the reclamation of bog-land at Kylemore is first to remove the excess of water, by "the big drain and the secondary drains," which must be cut deep enough to go right down to the gravel below. These are supplemented by the "sheep-drains," or surface-drains, which are about twenty inches wide at top, and narrow downward to six inches at bottom. They run parallel to each other, with a space of about ten yards between, and cost one penny per six yards.

This first step having been made, the bog is left for two years, during which it drains, consolidates, and sinks somewhat. If the bog is deep, the turf, which has now become valuable by consolidation, should be cut.

After this it is left about two years longer, with the drains still open. Then the drains are cleared and deepened, and a wedge-shaped sod, too wide to reach the bottom, is rammed in so as to leave below it a permanent tubular covered drain, which is thus made without the aid of any tiles or other outside material. The drainage is now completed, and the surface prepared for the important operation of dressing with lime, which, as the people expressively say, "boils the bog," and converts it into a soil suitable for direct agricultural operations.

Potatoes and turnips may now be set in "lazy bed" ridges. Mr. Mitchell Henry says, "Good herbage will grow on the bog thus treated; but as much as possible should at once be

put into root-crops, with farm-yard manure for potatoes and turnips. The more lime you give the better will be your crop; and treated thus there is no doubt that even during the first year land so reclaimed will yield remunerative crops." And further, that "after being broken up a second time the land materially improves, and becomes doubly valuable." Also that he has no doubt that "all bog-lands may be thus reclaimed, but it is up-hill work, and not remunerative to attempt the reclamation of bogs that are more than four feet in depth."

There is another and a simpler method of dealing with bogs—viz. setting it into narrow ridges; cutting broad trenches between the ridges; piling the turf cut out from these trenches into little heaps a few feet apart, burning them, and spreading the ashes over the ridges. This is rather largely practised on the coast of Donegal, in conjunction with sea-weed manuring, and is prohibited in other parts of Ireland as prejudicial to the interests of the landlord.

We shall now proceed to the philosophy of these processes.

First, the drainage. Everybody in Ireland knows that the bog holds water like a sponge, and in such quantities that ordinary vegetation is rotted by the excess of moisture. There is good reason to believe that the ancient forests, which once occupied the sites of most of the Irish bogs, were in some cases destroyed by the rotting of their stems and roots in the excess of vegetable soil formed by generations upon generations of fallen leaves, which, in a humid climate like that of Ireland, could never become drained or air-dried.

But this is not all. There is rotting and rotting. When the rotting of vegetable matter goes on under certain conditions it is highly favorable to the growth of other vegetation, even of the vegetation of the same kind of plants as those supplying the rotting material. Thus rotten and rotting straw is a good manure for wheat; and the modern scientific vine-grower carefully places the dressing of his vines about their roots, in order that they may rot, and supply the necessary salts for future growth. The same applies generally; rotting cabbage leaves supply the best of manure for cabbages; rotting rhubarb leaves for rhubarb; rose leaves for rose trees; and so on throughout the vegetable kingdom.

Why, then, should the bog-rotting be so exceptionally malignant? As I am not aware that any answer has been given to this question, I will venture upon one of my own. It appears to be mainly due to the excess of moisture preventing that slow combustion of vegetable carbon which occurs wherever vegetable matter is heaped together and *slightly* moistened. We see this going on in steaming dunghills; in hayricks that have been stacked when imperfectly dried; in the spontaneous combustion of damp cotton in the holds of ships, and in factories where cotton-waste has been carelessly heaped; and in cucumber-frames and the other "hot-beds" of the gardener.

In ordinary soils this combustion goes on more slowly, but no less effectively, than in these cases. In doing so it maintains a certain degree of warmth about the roots of the plants that grow there, and *gradually* sets free the soluble salts which the rotting vegetables contain, and supplies them to the growing plants as manure, at the same time forming the humus so essential to vegetation.

A great excess of water, such as soddens the bog, prevents this, and also carries away any small quantity of soluble nutritious salts the soil may contain. Thus instead of being warmed and nourished by slight humidity, and consequent oxidation, the bog soil is chilled and starved by excess of water.

The absolute necessity of the first operation—that of drainage—is thus rendered obvious; and I suspect that the need of four years' rest, upon which Mr. MacAlister insists, is somehow connected with a certain degree

of slow combustion that accompanies and partially causes the consolidation of the bog. I have not yet had an opportunity of testing this by inserting thermometers in bogs under different conditions, but hope to do so.

The liming next demands explanation. Mr. Henry says that "it leaves the soil sweetened by the neutralization of its acids."

In order to test this theory I have digested (*i.e.*, soaked) various samples of turf cut from Irish bogs in distilled water, filtered off the water, and examined it. I find that when this soaking has gone far enough to give the water a coloring similar to that which stands in ordinary bogs, the acidity is very decided—quite sufficiently so to justify this neutralization theory as a partial explanation. There is little reason to doubt that the lime is further effective in enriching the soil; or, in the case of pure bogs, that it forms the soil by disintegrating and decomposing the fibrous vegetable matter, and thus rendering it capable of assimilation by the crops.

Another effect which the lime must produce is the liberation of free ammonia from any fixed salts that may exist in the bog.

The bog-burning method of reclamation is easily explained. In the first place, the excessive vegetable encumbrance is reduced in quantity, and the remaining ashes supply the surface of the bog on which they rest with the non-volatile salts that originally existed in the burnt portions of the bog. In other words, they concentrate in a small space the salts that were formerly distributed too sparsely through the whole of the turf which was burnt.

As there are great differences in the composition of different bogs, especially in this matter of mineral ash, it is evident that the success of this method must be very variable, according to the locality.

On discussing this method with Mr. MacAlister (Mr. Henry's steward, under whose superintendence these reclamation works are carried out) he informed me that the bogs on the Kylemore estate yield a very small amount of ash—a mere impalpable powder that a light breath might blow away; that it was practically valueless, excepting from the turf taken at nearly the base of the bog. The ash I examined where the bog-burning is extensively practised in Donegal was quite different from this. The quantity was far greater, and its substance more granular and gritty. It, in fact, formed an important stratum when spread over the surface of the ridges. These differences of composition may account for the differences of opinion and practice which prevail in different districts. It affords a far more rational explanation than the assumption that all such contradictions arise from local stupidities.

There is one evil, however, which is common to all bog-burning as compared with liming—it must waste the ammoniacal salts, as they are volatile, and are driven away into the air by the heat of combustion. Somebody may get them when the rain washes them down to the earth's surface again; but the burner himself obtains a very small share in this way.

We may therefore conclude that where lime is near at hand, bog-burning is a rude and wasteful, a viciously indolent mode of reclamation. It is only desirable where limestone is so distant that the expense of carriage renders lime practically unattainable, and where the bog itself is rich in mineral matter, and so deep and distant from a fuel demand, that it may be burned to waste without any practical sacrifice. Under such conditions it may be better to burn the bog than leave it in hopeless and worthless desolation.

I cannot conclude without again adverting to the importance of this subject, and affirming with the utmost emphasis, that the true Irish patriot is not the political orator, but he who by practical efforts, either as capitalist, laborer, or teacher, promotes the

reclamation of the soil of Ireland, or otherwise develops the sadly neglected natural resources of the country.

With Mr. Mitchell Henry's permission I append to the above his own description of the results of his experiment, originally communicated in a letter to the "Times"; at the same time thanking him for his kind reception of a stranger at Kylemore Castle, and the facilities he afforded me for studying the subject on the spot.

"The interesting account you lately published of the extensive reclamations of His Grace the Duke of Sutherland, under the title of 'An Agricultural Experiment,' has been copied into very many newspapers, and must have afforded a welcome relief to thousands of readers glad to turn for a time from the terrible narratives that come to us from the East. If you will allow me, I should like to supplement your narrative by a rapid sketch of what has been done here during the last few years, on a much humbler scale, in the case of land similar, and some of it almost identical, with that in Sutherlandshire.

"The twelve *corps d'armée* under the Duke's command, in the shape of the twelve steam-engines and their plows, engaged in subduing the stubborn resistance of the unreclaimed wilds of Sutherlandshire, suggest to the mind the triumphs of great warriors, and fill us with admiration—not always excited by the details of great battles; but, as great battles can be fought seldom, and only by gigantic armies and at prodigious expense, so reclamation on such a scale is far beyond the opportunities or the means of most of us; while many may, perhaps, be encouraged to attempt work similar to that which has been successfully carried out here.

"And, first of all, a word as to the all-important matter of cost. Does it pay?

"Including farm-buildings and roads, the reclamations here have cost on an average 13*l.* an acre, which, at 5 per cent., means an annual rent-charge of 13*s.*, to which is to be added a sum of from 1*s.* to 3*s.*, the full annual value of the unreclaimed land. It is obvious that if we start with an outlay of 30*l.* *plus* the 1*s.* to 3*s.* of original rent, such an amount would usually be found prohibitory; but, on the other hand, excellent profits may be made if the expenditure is so kept down that the annual rent is not more than from 15*s.* to 18*s.* per acre. Before entering into further details, let me say that I claim no credit for originality in what has been done. The like has been effected on numerous properties in Ireland in bygone days, and is daily being carried out by the patient husbandman who year by year with his spade reclaims a little bit from the mountain-side. And you must allow me emphatically to say that what has been done here economically and well would not have been done except for the prudence, patience, and thoughtful mind of my steward, Archibald MacAlister, a county Antrim man, descended from one of the race of Highland Catholic Scotch settlers who have peopled the North of Ireland and added so much to its prosperity.

"The Pass of Kylemore, in which I live, is undoubtedly favorably situated for reclamation, for there is but little very deep bog, and there is abundance of limestone. In former ages it must have been an estuary of the sea, with a river flowing through it, now represented by a chain of lakes and the small rapid river Dowris. The subsoil is sand, gravel, and schist rock, with peat of various depths grown upon it. As by the elevation of the land the sea long ages ago was driven back, the mossy growth of peat commenced, followed by pine and yew trees, of which the trunks and roots are abundantly found; but, except over a space of about 400 acres, every tree that formerly clothed the hillsides has been cut down or has totally disappeared. The general result is that we have a pass several miles long, bounded on the north and the south by a chain of rugged mountains

of some 1500 or 1800 feet in height, while the east is blocked up by a picturesque chain running north and south, and separating the Joyce country from Connemara proper, the west being open to the Atlantic. The well-known Killery Bay, or Fiord, would, I doubt not, present an exact resemblance to Kylemore if the sea, which now flows up to its head, were driven out. There are miles of similar country in Ireland, waiting only for the industry of man, where, as here, there exist extensive stretches of undulating eskers, covered with heather growing on the light clay, with a basis of gravel or sand.

"A considerable difference exists between the reclamation of the flat parts, where the bog is pretty deep, and the hill-sides, where there is little or no bog. Yet it is to be remembered that bog is nothing more than vegetable matter in a state of partial decomposition, and holding water like a sponge. The first thing is to remove the water by drains, some of which—that is, the big drain and the secondary drains—must go right down to the gravel below; but the other drains—called sheep-drains—need not, and, indeed, must not be cut so deep. The drains are cut wedge-shape by what are called Scotch tools, which employ three men—two to cut and one to hook out the sods; and all that is requisite to form a permanent drain is to replace the wedge-shaped sod, and ram it down between the walls of the drain, where it consolidates and forms a tube which will remain open for an indefinite number of years. We have them here as good as new, made twenty-five years ago; and at Chat Moss, in Lancashire, they are much older. After land has been thus drained—but not too much drained, or it will become dry turf—the surface begins to sink; what was tumid settles down, and in the course of a few months the land itself becomes depressed on the surface and much consolidated. Next it is to be dug by spade-labor or plowed. We use oxen largely for this purpose, and, strange to say, the best workers we find to be a cross with the Alderney, the result being a light, wiry little animal, which goes gayly over the ground, is easy to feed, and very tractable. The oxen are trained by the old wooden neck-yoke; but, when well broken, work in collars, which seem more easy to them. Horses on very soft land work well in wooden pattens. After the land has been broken up, a good dressing of lime is to be applied to it, and this, in the expressive language of the people here, "boils the bog"—that is, the lime causes the vegetable matter, formerly half decomposed, to become converted into excellent manure. This leaves the soil sweetened by the neutralization of its acids, and in a condition pretty easily broken up by the chain-harrow; or, what is better still, by Randall's American revolving harrow.

"Good herbage will grow on bog thus treated, but as much as possible should at once be put into root-crops, with farm-yard manure for potatoes and turnips. The more lime you give the better will be your crop, and, treated thus, there is no doubt that even during the first year land so reclaimed will yield remunerative crops. People ask, 'But will not the whole thing go back to bog?' Of course it will if not kept under proper rotation, which we find to be one of five years—namely, roots followed by oats, laid down with clover and grass seed, which remains for two years. After being broken up a second time, the land materially improves and becomes doubly valuable. I have no doubt that all bog-lands may be thus reclaimed, but it is up-hill work and not remunerative to attempt the reclamation of bogs that are more then four feet in depth.

"And here I will make a remark as to the effects of drainage in a wet country. By no means does the whole effect result from raising the temperature of the soil; there is something else as important, and that is the supply of ammonia, brought down from the skies in the rain, which, with other

fertilizing matter, is caught, detained, and absorbed in the soil. A well-drained field becomes, in fact, just like a water-meadow over which a river flows for a part of a year; and thus the very wetness of the climate may be made to reduce the supply of ammoniacal manures, so expensive to buy.

"The porous, well-drained soil carries quickly off the superfluous moisture, while the ammonia is absorbed by the roots and leaves of the plants. An excessive bill for ammoniacal manures has been the ruin of many a farmer, and our aim in Ireland should be to secure good crops by thorough drainage and constant stirring of the soil, without much outlay for concentrated manures. At the same time, I ought to remark that we have grown excellent potatoes by using 5*l.* worth per acre of superphosphate and nitrate of soda in cases in which our farmyard manure has fallen short.

"The reclamation of mountain-land as distinguished from bog-land can best be illustrated by a record of what has been accomplished on two farms here. Three years ago the leases of two upland farms fell in, and I took them into my own hands. The first consists of 600 acres, one-half a nearly level flat of deepish bog running alongside the river, the other half moor heath, which with difficulty supported a few sheep and cattle.

"There had never been any buildings on this land, nor had a spade ever been put into it; and the tenant, being unable to pay his rent of 15*l.* a year for the 600 acres, was glad to give it up for a moderate consideration. The first thing accomplished was to fence and drain thoroughly as before described, and the best half of the land was then divided into forty-acre fields. Exactly now two years ago—on September 15—a little cottage and a stable for a pair of horses and a pair of bullocks was completed and tenanted by two men and a boy. They plowed all the week and came home on Saturdays to draw their supply of food and fodder for the ensuing seven days, thus approximating very nearly to the position of settlers in a new country. We limed all the land we could, manured part of it with seaweed and part with the farm manure made by the horses and oxen which were at work, and cropped with roots such as turnips and potatoes. A good portion we sowed with oats out of the lea, but the most satisfactory crop we found to be rape and grasses mixed, for on the best of the land they form at once an excellent permanent pasture. We have now had two crops from this land; and I venture to say that the thirteen stacks of oats and hay gathered in in good condition, and the turnips and roots now growing, which are not excelled in the county Galway—except those of Lord Clancarty at Ballinasloe, who has grown 110 tons of turnips to the Irish acre, equal to upward of 68 tons to the acre here—present a picture most gratifying and cheering in every way.

"The second farm of 240 acres, which adjoins this, had a good building on it; but, having been let on lease at about 10*s.* an acre to a large grazier whose stock-in-trade was a horse, a saddle, and a pair of shears, had not been cultivated or improved.

"Similar proceedings on this farm have produced similar results; and, if now let in the market, I have no doubt that after two years of good treatment these farms would be let at 20*s.* an acre, and I do not despair of doubling this figure in the course of time.

"The exact weight of the turnip crop this season is, on raw bog, drained, limed, and cropped this year for the first time, 24 tons per acre; manure, seaweed. On land plowed but not cropped, last year 23½ tons; mixed mineral manure. On and from which a crop of oats had previously been taken, 29 tons; manure, farmyard, with 3 cwt. per acre mineral manure.

"Last year my excellent steward, Mr. MacAlister, visited the Duke of Sutherland's reclamations in Scot-

land, and was kindly and hospitably received. He found the land and the procedure adopted almost identical, with the conviction that oxen and horses will suit us better at the present time than steam culture, chiefly on the score of economy. He also visited the Bridgewater Estate at Chat Moss, near Manchester, where so much has been done to bring the deep peat into cultivation, and he found the system that has been followed there for so many years to be like that described above, marl, however, being used in the place of lime."

At the time of my visit to Kylemore the hay crops were down and partly carried on the reclaimed bog-land above described. The contrast of its luxuriance with the dark and dreary desolation of the many estates I had seen during three summers' wanderings through Ireland added further proof of the infamy of the majority of Irish landlords, by showing what Ireland would have been had they done their duty.

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## THE COLORING OF GREEN TEA.

The following is a copy of my report to the "Grocer" on a sample of the ingredients actually used by the Chinese for coloring of tea, which sample was sent to the "Grocer" office by a reliable correspondent at Shanghai (November, 1873). I reprint it because the subject has a general interest and is commonly misunderstood:—

I have examined the blue and the yellowish-white powders received from the office, and find that the blue is not indigo, as your Shanghai correspondent very naturally supposes, but is an ordinary commercial sample of Prussian blue. It is not so bright as some of our English samples, and by mere casual observation may easily be mistaken for indigo. Prussian blue is a well-known compound of iron, cyanogen, and potassium. Commercial samples usually contain a little clayey or other earthy impurities, which is the case with this Chinese sample. There are two kinds of Prussian blue—the insoluble, and the basic or soluble. The Chinese sample is insoluble.

This is important, seeing that we do not eat our tea-leaves, but merely drink an infusion of them; and thus even the very small quantity which faces the tea-leaf remains with the spent leaves, and is not swallowed by the tea-drinker, who therefore need have no fear of being poisoned by this ornamental adulterant.

Its insolubility is obvious, from the fact that green tea does not give a blue infusion, which would be the case if the Prussian blue were dissolved.

There are some curious facts bearing on this subject and connected with the history of the manufacture of Prussian blue. Messrs. Bramwell, of Newcastle-on-Tyne, who may be called the fathers of this branch of industry, established their works about a century ago. It was first sold at two guineas per lb.; in 1815 it had fallen to 10*s.* 6*d.*, in 1820 to 2*s.* 6*d.*, then down to 1*s.* 9*d.* in 1850. I see by the Price Current of the "Oil Trade Review" that the price has recently been somewhat higher.

In the early days of the trade a large portion of Messrs. Bramwell's produce was exported to China. The Chinese then appear to have been the best customers of the British manufacturers of this article. Presently, however, the Chinese demand entirely ceased, and it was discovered that a common Chinese sailor, who had learned something of the importation of this pigment to his native country, came to England in an east Indiaman, visited, or more probably obtained employment at a Prussian blue manufactory, learned the process, and, on his return to China, started there a manufactory of his own, which was so successful that in a short time the whole of the Chinese demand was supplied by native manufacture; and thus ended our export trade. Those

who think the Chinese are an unteachable and unimprovable people may reflect on this little history.

The yellowish powder is precisely what your Shanghai correspondent supposes. It is steatite, or "soapstone." This name is very deceptive, and, coupled with the greasy or unctuous feel of the substance, naturally leads to the supposition that it is really, as it appears, an oleaginous substance. This, however, is not the case. It is a compound of silicia, magnesia, and water, with which are sometimes associated a little clay and oxide of iron. Like most magnesian minerals, it has a curiously smooth or slippery surface, and hence its name. It nearly resembles meerschaum, the smoothness of which all smokers understand.

When soapstone is powdered and rubbed over a moderately rough surface, it adheres, and forms a shining film; just as another unctuous mineral, graphite (the "blacklead" of the housemaid), covers and polishes ironwork. On this account, soapstone is used in some lubricating compounds, for giving the finishing polish to enameled cards, and for other similar purposes.

With a statement of these properties before us, and the interesting description of the process by your Shanghai correspondent, the whole riddle of green-tea coloring and facing is solved. The Prussian blue and soapstone being mixed together when dry in the manner described, the soapstone adheres to the surface of the particles of blue, and imparts to them not only a pale greenish color, but also its own unctuous, adhesive, and polishing properties. The mixture being well stirred in with the tea-leaves, covers them with this facing, and thus gives both the color and peculiar pearly luster characteristic of some kinds of green tea. I should add that the soapstone, like the other ingredient, is insoluble, and therefore perfectly harmless.

Considering the object to be attained, it is evident from the above that John Chinaman understands his business, and needs no lessons from European chemists. It would puzzle all the Fellows of the Chemical Society, though they combined their efforts for the purpose, to devise a more effective, cheap, simple, and harmless method of satisfying the foolish demand for unnaturally colored tea-leaves.

When the tea-drinking public are sufficiently intelligent to prefer naturally colored leaves to the ornamental stuff they now select, Mr. Chinaman will assuredly be glad enough to discontinue the addition of the Prussian blue, which costs him so much more per lb. than his tea leaves, and will save him the trouble of the painting and varnishing now in demand.

In the mean time, it is satisfactory to know that, although a few silly people may be deceived, nobody is poisoned by this practice of coloring green tea. I say "a few silly people," for there can be only a few, and those very silly indeed, who judge of their tea by its appearance rather than by the quality of the infusion it produces.

With these facts before us it is not difficult to trace the origin of the oft-repeated and contradicted statement that copper is used in coloring green tea. One of the essential ingredients in the manufacture of Prussian blue is sulphate of iron, the common commercial name of which is "green coperas." It is often supposed to contain copper but this is not the case.

Your Shanghai correspondent overrates the market value of soapstone, when he supposes that Chinese wax may be used as a cheap substitute. In many places—as, for instance, the "Lizard" district of Cornwall—great veins of this mineral occur which, if needed, might be quarried in vast abundance, and at very little cost on account of its softness. The romantic scenery of Kynance Cove, its caverns, its natural arches, the "Devil's Bellows," the "Devil's Post-office," the "Devil's Cauldrons," and other fantastic formations of this part of the coast, attributed to his Satanic Majesty or the Druids, are the natural re-

sults of the waves beating away the veins of soft soapstone, and leaving the deformed skeleton rocks of harder serpentine behind.

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## "IRON FILINGS" IN TEA.

I HAVE watched the progress of the tea controversy and the other public performances of the public analysts with considerable interest; it might have been with amusement, but for the melancholy degradation of chemical science which they involve.

Among the absurdities and exaggerations which for some years past have been so industriously trumpeted forth by the pseudo-chemists who trade upon the adulteration panic and consequent demand for chemical certificates of purity, the continually repeated statements concerning the use of iron filings as a fraudulent adulterant of tea takes a prominent place. I need scarcely remark that, in order to form such an adulterant, the quantity added must be sufficiently great to render its addition commercially profitable to an extent commensurate with the trouble involved.

The gentlemen who, since the passing of the Adulteration Act, have by some kind of inspiration suddenly become full-blown chemists, have certified to willful adulteration of tea with iron filings, and have obtained *convictions* on such certificates, when, according to their own statement, the quantity contained has not exceeded 5 per cent. in the cheapest qualities of tea. Now, the price of such tea to the Chinaman tea-grower, who is supposed to add these iron filings, is about fourpence to sixpence per pound; and we are asked to believe that he will fraudulently deteriorate the market value of his commodity for the sake of this additional 1–20th of weight. Supposing that he could obtain his iron filings at twopence per pound, his total gain would thus be about 1–10th of a penny per pound. But can he obtain such iron filings in the quantity required at such a price? A little reflection on a few figures will render it evident that he cannot, and that such adulteration is utterly impossible.

I find by reference to "The Grocer" of November 8, that the total deliveries of tea into the port of London during the first ten months of 1872 were 142,429,337 lbs., and during the corresponding period of 1873, 139,092,409 lbs. Of this about 8½ millions of pounds in 1873, and 10 millions of pounds in 1872, were green, the rest black. This gives in round numbers about 160 millions of pounds of black tea per annum, of which above 140 millions come from China. As the Russians are greater tea-drinkers than ourselves—the Americans and British colonists are at least equally addicted to the beverage, and other nations consume some quantity—the total exports from China may be safely estimated to reach 400 or 500 millions of pounds.

Let us take the smaller figure, and suppose that only one fourth of this is adulterated, to the extent of 5 per cent., with iron filings. How much would be required? Just five millions of pounds per annum.

It must be remembered that *coarse* filings could not possibly be used; they would show themselves at once to the naked eye as rusty lumps, and would shake down to the bottom of the chest; neither could borings, nor turnings, nor plane-shavings be used. Nothing but *fine* filings would answer the supposed purpose. I venture to assert that if the China tea-growers were to put the whole world under contribution for their supposed supply of fine iron filings, this quantity could not be obtained.

Let any one who doubts this borrow a blacksmith's vise, a fine file, and a piece of soft iron, then take off his coat and try how much labor will be required to produce a single ounce of filings, and also bear in mind that fine files are but very little used in the manufacture of iron. As the price of a commodity rises when the

demand exceeds the supply the Chinaman would have to pay far more for his adulterant than for the leaves to be adulterated. As Chinese tea-growers are not public analysts, we have no right to suppose that they would perpetrate any such foolishness.

The investigations recently made by Mr. Alfred Bird, of Birmingham, show that the iron found in tea-leaves is not in the metallic state, but in the condition of oxide; and he confirms the conclusions of Zöller, quoted by Mr. J. A. Wanklyn in the "Chemical News" of October, 10th—viz., that compounds of iron naturally exist in genuine tea. It appears, however, that the ash of many samples of *black* tea contains more iron than naturally belongs to the plant; and, accepting Mr. Bird's statement, that this exists in the leaf as oxide mixed with small siliceous and micaceous particles, I think we may find a reasonable explanation of its presence without adopting the puerile theory of the adulteration maniac, who, in his endeavor to prove that everybody who buys or sells anything is a swindler, has at once assumed the impossible addition of iron filings as a make-weight.

In the first place we must remember that the commodity in demand is *black* tea, and that ordinary leaves dried in an ordinary manner are not black, but brown. Tea-leaves, however, contain a large quantity of tannin, a portion of which is, when heated in the leaves, rapidly convertible into gallo-tannic or tannic acid. Thus a sample of tea rich in iron would, when heated in the drying process, become, by the combination of this tannic acid with the iron it contains, much darker than ordinary leaves or than other teas grown upon less ferruginous soils and containing less iron.

This being the case, and a commercial demand for *black* tea having become established, the tea-grower would naturally seek to improve the color of his tea, especially of those samples naturally poor in iron, and a ready mode of doing this is offered by stirring in among the leaves while drying a small additional dose of oxide of iron, if he can find an oxide in such a form that it will spread over the surface of the leaf as a thin film. Now, it happens that the Chinaman has lying under his feet an abundance of material admirably adapted for this purpose—viz., red hæmatite, some varieties of which are as soft and unctuous as graphite, and will spread over his tea-leaves exactly in the manner required. The micaceous and siliceous particles found by Mr. Bird are just what should be found in addition to oxide of iron, if such hæmatite were used.

The film of oxide thus easily applied, and subjected to the action of the exuding and decomposing extractive matter of the heated leaves, would form the desired black dye or "facing."

The knotty question of whether this is or is not an adulteration is one that I leave to lawyers to decide, or for those debating societies that discuss such interesting questions as whether an umbrella is an article of dress. If it is an adulteration, and, as already admitted, is not at all injurious to health, then all other operations of dyeing are also adulterations; for the other dyers, like the Chinaman, add certain impurities to their goods—the silk, wool, or cotton—in order to alter their natural appearance, and to give them the false facing which their customers demand, but with this difference, if I am right in the above explanation: that in darkening tea nothing more is done but to increase the proportion of one of its natural ingredients, and to intensify its natural color; while in the dyeing of silk, cotton, or wool, ingredients are added which are quite foreign and unnatural, and the natural color of the substance is altogether falsified.

The above appeared in the "Chemical News" November 21, 1873, when the adulteration in question was generally believed to be commonly per-

petrated, and many unfortunate shopkeepers had been and were still being summoned to appear at Petty Sessions, etc., and publicly branded as fraudulent adulterators on the evidence of the newly-fledged public analysts, who confidently asserted that they found such filings mixed with the tea. Some discussion followed in subsequent numbers of the "Chemical News," but it only brought out the fact that "finely divided iron" exists in considerable quantities in Sheffield,—may be "begged," as Mr. Alfred H. Allen (an able analytical chemist, resident in Sheffield) said. The fact that such finely divided iron is thus without commercial value still further confirms my conclusion that it is not used for the adulteration of tea. If it were, its collection would be a regular business, and truckloads would be transmitted from Sheffield to London, the great center of tea-importation. No evidence of any commercial transactions in iron filings or iron dust for such purposes came forward in reply to my challenge.

The practical result of the controversy is that iron filings are no longer to be found in the analytical reports of the adulteration of tea.

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## THE ORIGIN OF SOAP.

A HISTORY of soap would be very interesting. Who invented it? When and where did it first come into common use? How did our remote ancestors wash themselves before soap was invented? These are historical questions that naturally arise at first contemplation of the subject; but, as far as we are aware, historians have failed to answer them. We read a great deal in ancient histories about anointing with oil and the use of various cosmetics for the skin, but nothing about soap.

These ancients must have been very greasy people, and I suspect that they washed themselves pretty nearly in the same way as modern engine-drivers clean their fingers, by wiping off the oil with a bit of cotton-waste.

We are taught to believe that the ancient Romans wrapped themselves round with togas of ample dimensions, and that these togas were white. Now, such togas, after encasing such anointed oily skins, must have become very greasy. How did the Roman laundresses or launders—historians do not indicate their sex—remove this grease? Historians are also silent on this subject.

A great many curious things were found buried under the cinders of Vesuvius in Pompeii, and sealed up in the lava that flowed over Herculaneum. Bread, wine, fruits, and other domestic articles, including several luxuries of the toilet, such as pomades or pomade-pots, and rouge for painting ladies' faces, but no soap for washing them. In the British Museum is a large variety of household requirements found in the pyramids of Egypt, but there is no soap, and we have not heard of any having been discovered there.

Finding no traces of soap among the Romans, Greeks, or Egyptians, we need not go back to the pre-historic "cave men," whose flint and bone implements were found imbedded side by side with the remains of the mammoth bear and hyena in such caverns as that at Torquay, where Mr. Pengelly has, during the last eighteen years, so industriously explored.

All our knowledge, and that still larger quantity, our ignorance, of the habits of antique savages, indicate that solid soap, such as we commonly use, is a comparatively modern luxury; but it does not follow that they had no substitute. To learn what that substitute may probably have been we may observe the habits of modern savages, or primitive people at home and abroad.

This will teach us that clay, especially where it is found having some of the unctuous properties of fuller's earth, is freely used for lavatory purposes, and was probably used by the Romans, who were by no means re-

markable for anything approaching to true refinement. They were essentially a nasty people, the habits of the poor being "cheap and nasty"; of the rich, luxurious and nasty. The Roman nobleman did not sit down to dinner, but sprawled with his face downward, and took his food as modern swine take theirs. At grand banquets, after gorging to repletion, he tickled his throat in order to vomit and make room for more. He took baths occasionally, and was probably scoured and shampooed as well as oiled, but it is doubtful whether he performed any intermediate domestic ablutions worth naming.

A refinement upon washing with clay is to be found in the practice once common in England, and still largely used where wood fires prevail. It is the old-fashioned practice of pouring water on the wood ashes, and using the "lees" thus obtained. These lees are a solution of alkaline carbonate of potash, the modern name of potash being derived from the fact that it was originally obtained from the ashes under the pot. In like manner soda was obtained from the ashes of seaweeds and of the plants that grow near the sea-shore, such as the *salsover soda*, etc.

The potashes or pearlashes being so universal as a domestic bye-product, it was but natural that they should be commonly used, especially for the washing of greasy clothes, as they are to the present day. Upon these facts we may build up a theory of the origin of soap.

It is a compound of oil or fat with soda or potash, and would be formed accidentally if the fat on the surface of the pot should boil over and fall into the ashes under the pot. The solution of such a mixture if boiled down would give us soft-soap.

If oil or fat became mixed with the ashes of soda plants, it would produce hard soap. Such a mixture would most easily be formed accidentally in regions where the olive flourishes near the coast, as in Italy and Spain for example, and this mixture would be Castile soap, which is still largely made by combining refuse or inferior olive oil with the soda obtained from the ashes of seaweed.

The primitive soap-maker would, however, encounter one difficulty—that arising from the fact that the pot ash or soda obtained by simple burning of the wood or seaweed is more or less combined with carbonic acid, instead of being all in the caustic state which is required for effective soap-making. The modern soap-maker removes this carbonic acid by means of caustic lime which takes it away from the carbonate of soda or carbonate of potash by simple exchange—*i.e.*, caustic lime *plus* carbonate of soda becoming caustic soda *plus* carbonate of lime, or carbonate of potash *plus* caustic lime becoming caustic potash *plus* carbonate of lime.

How the possibility of making this exchange became known to the primitive soap-maker, or whether he knew it at all, remains a mystery, but certain it is that it was practically used long before the chemistry of the action was at all understood. It is very probable that the old alchemists had a hand in this.

In their search for the philosopher's stone, the elixir of life or drinkable gold, and for the universal solvent, they mixed together everything that came to hand, they boiled everything that was boilable, distilled everything that was volatile, burnt everything that was combustible, and tortured all their "simples" and their mixtures by every conceivable device, thereby stumbling upon many curious, many wonderful, and many useful results. Some of them were not altogether visionary—were, in fact, very practical, quite capable of understanding the action of caustic lime on carbonate of soda, and of turning it to profitable account.

It is not, however, absolutely necessary to use the lime, as the soda plants when carefully burned in pits dug in the sand of the sea-shore may contain but little carbonic acid if the ash is fluxed into a hard cake like that

now commonly produced, and sold as "soda ash." This contains from 3 to 30 per cent. of carbonate, and thus some samples are nearly caustic, without the aid of lime.

As cleanliness is the fundamental basis of all true physical refinement, it has been proposed to estimate the progress of civilization by the consumption of soap, the relative civilization of given communities being numerically measured by the following operation in simple arithmetic:—Divide the total quantity of soap consumed in a given time by the total population consuming it, and the quotient expresses the civilization of that community.*

The allusion made by Lord Beaconsfield, at the Lord Mayor's dinner in 1879, to the prosperity of our chemical manufactures was a subject of merriment to some critics, who are probably ignorant of the fact that soap-making is a chemical manufacture, and that it involves many other chemical manufactures, some of them, in their present state, the results of the highest refinements of modern chemical science.

While the fishers of the Hebrides and the peasants on the shores of the Mediterranean are still obtaining soda by burning seaweed as they did of old, our chemical manufacturers are importing sulphur from Sicily and Iceland, pyrites from all quarters, nitrate of soda from Peru and the East Indies, for the manufacture of sulphuric acid, by the aid of which they now make enormous quantities of caustic soda from the material extracted from the salt mines of Cheshire and Droitwich. These sulphuric acid works and these soda works are among the most prosperous and rapidly growing of our manufacturing industries, and their chief function is that of ministering to soap-making, in which Britain is now competing triumphantly with all the world.

By simply considering how much is expended annually for soap in every decent household, and adding to this the quantity consumed in laundries and by our woollen and cotton manufacturers, a large sum total is displayed. Formerly, we imported much of the soap we used at home; now, in spite of our greatly magnified consumption, we supply ourselves with all but a few special kinds, and export very large and continually increasing quantities to all parts of the world; and if the arithmetical rule given above is sound, the demand must steadily increase as civilization advances.

* The scientific pedant of the Middle Ages displayed his profundity by continually quoting Aristotle and other "ancients." His modern successor does the like by decorating his pages with displays of algebraical formula. In order to secure the proper respect of *my* readers I here repeat the equation that I enunciated many years ago, '$c = \frac{s}{p}$' where $c$ stands for civilization, $s$ for the quantity of soap consumed per annum, and $p$ the population of a given community.

## THE ACTION OF FROST IN WATER-PIPES AND ON BUILDING MATERIALS.

Popular science has penetrated too deeply now to render necessary any refutation of the old popular fallacy which attributed the bursting of water-pipes to the thaw following a frost; everybody now understands that the thaw merely renders the work of the previous freezing so disastrously evident. Nevertheless, the general subject of the action of freezing water upon our dwellings is not so fully understood by all concerned as it should be. Builders and house-owners should understand it thoroughly, as most of the domestic miseries resulting from severe winters may be greatly mitigated, if not entirely prevented, by scientific adaptation in the course of building construction. Now-a-days tenants know something about this and select accordingly. Thus the market value of a building may be increased by such adaptation.

Solids, liquids, and gases expand as they are heated. This great gen-

eral law is, however, subject to a few exceptions, the most remarkable of which is that presented by water. Let us suppose a simple experiment. Imagine a thermometer tube with its bulb and stem so filled with water that when the water is heated nearly to its boiling point it will rise to nearly the top of the long stem. Now let us cool it. As the cooling proceeds the water will descend, and this descending will continue until it attains the temperature marked on our ordinary thermometer as 39°, or more strictly 39.2; then a strange inversion occurs. As the temperature falls below this, the water rises gradually in the stem until the freezing point is reached.

This expansion amounts to $\frac{1}{7692}$ part of the whole bulk of the water, or 100,000 parts become 100,013. So far the amount of expansion is very small, but this is only a foretaste of what is coming. Lowering the temperature still further, the water begins to freeze, and at the moment of freezing it expands suddenly to an extent equaling $\frac{1}{15}$ of its bulk, *i.e.*, of the bulk of so much water as becomes solidified. The temperature remains at 32° until the whole of the water is frozen.

Fortunately for us, the freezing of water is always a slow process, for if this conversion of every 15 gallons into 16 took place suddenly, all our pipes would rip open with something like explosive violence. But such sudden freezing of any considerable quantity of water is practically impossible, on account of the "latent heat" of liquid water, which amounts to 142½°. All this is given out in the act of freezing. It is this giving out of so much heat that keeps the temperature of freezing water always at 32°, even though the air around may be much colder. No part of the water can fall below 32° without becoming solid, and that portion which solidifies gives out enough heat to raise 142½ times its own quantity from 31° to 32°.

The slowness of thawing is due to the same general fact. An instructive experiment may be made by simply filling a saucepan with snow or broken ice, and placing it over a common fire. The slowness of the thawing will surprise most people who have not previously tried the experiment. It takes about as long to melt this snow as it would to raise an equal weight of water from 32° to 174°. Or, if a pound of water at 174° be mixed with a pound of snow at 32°, the result will be two pounds of water at 32°, 142° will have disappeared without making the snow any warmer, it will all have been used up in doing the work of melting.

The force with which the great expansion due to freezing takes place is practically irresistible. Strong pieces of ordnance have been filled with water, and plugged at muzzle and touch-hole. They have burst in spite of their great thickness and tenacity. Such being the case, it is at first sight a matter of surprise that frozen water-pipes, whether of lead or iron, ever stand at all. They would not stand but for another property of ice, which is but very little understood, viz., its *viscosity*.

This requires some explanation. Though ice is what we call a solid, it is not truly solid. Like other apparent solids it is not perfectly rigid, but still retains some degree of the possibility of flowing which is the characteristic of liquids. This has been shown by filling a bombshell with water, leaving the fuse-hole open and freezing it. A shell of ice is first formed on the outside, which of course plugs up the fuse-hole. Then the interior gradually freezes, but the expansion due to this forces the ice out of the fuse-hole as a cylindrical stick, just as putty might be squeezed out, only that the force required to mold and eject the ice is much greater.

I have constructed an apparatus which illustrates this very strikingly. It is an iron syringe with a cylindrical interior of about half an inch in diameter, and a terminal orifice of less than $\frac{1}{20}$ of an inch in diameter. Its

piston of metal is driven down by a screw. Into this syringe I place small fragments of ice, or a cylinder of ice fitted to the syringe, and then screw down the piston. Presently a thin wire of ice is squirted forth like vermicelli when the dough from which it is made is similarly treated, showing that the ice is plastic like the dough, provided it is squeezed with sufficient force.

The viscosity of ice is displayed on a grand scale in glaciers, the ice of which actually flows like a river down the glacier valley, contracting as the valley narrows and spreading out as it widens, just as a river would; but moving only a few inches daily according to the steepness of the slope and the season, slower in winter than in summer.

Upon this, and the slowness of the act of freezing, depends the possibility of water freezing in iron pipes without bursting them. Even iron yields a little before bursting, but ordinary qualities not sufficiently to bear the expansion of $\frac{1}{10}$ of their contents. What happens, then? The cylinder of ice contained in the tube elongates as it freezes, provided always the pipe is open at one or both ends. But there is a limit to this, seeing that the friction of such a tight-fitting core, even of slippery ice, is considerable, and if the pipe be too long, the resistance of this friction may exceed the resistance of tenacity of the pipe. I am unable to give any figures for such length; the subject does not appear to have been investigated as it should be, and as it might well be by our wealthy water companies.

We all know that lead pipes frequently succumb, but a little observation shows that they do so only after a struggle. The tenacity of lead is much less than that of iron (about $\frac{1}{30}$ of that of ordinary wrought iron), but it yields considerably before breaking. It has, in fact, the property of viscosity similar to that of ice. At Woolwich the lead used for elongated rifle bullets is squirted like the ice in my syringe above described, powerful hydraulic pressure being used.

This yielding saves many pipes. It would save all *new* pipes if the lead were pure and uniform; but as this is not the case, they may burst at a weak place, the yielding being shown by the bulge that commonly appears at the broken part.

From the above it may be easily understood that a pipe which is perfectly cylindrical—other conditions equal—will be less likely to burst than one which is of varying diameter, as the sliding from a larger to a smaller portion of the pipe must be attended with great resistance, or a certain degree of block, beyond what would be due to the mere friction along a pipe of uniform diameter.

Let us now consider the relative merits of lead and iron as material for water-pipes in places where exposure to frost is inevitable. Lead yields more than iron, and so far has an advantage; this, however, is but limited. As lead is practically inelastic, every stretch remains, and every stretch diminishes the capacity for further stretching; the lead thus stretched at one frost is less able to stretch again, and has lost some of its original tenacity. Hence the superiority of new leaden pipes. Iron is elastic within certain limits, and thus the iron pipe may yield a little without permanent strain or "distress," and if its power of elastic resistance is not exceeded, it regains its original size without becoming sensibly weaker. Add to this its great tenacity, its non-liability to be indented, or otherwise to vary in diameter, and we have a far superior material.

But this conclusion demands some qualification. There is iron and iron, cast iron and wrought iron, and very variable qualities of each of these. I need scarcely add that common brittle cast iron is quite out of the question for such purposes, though there is a new kind of cast-iron or semi-steel coming forward that may possibly supersede all other kinds; but this

opens too wide a subject for discussion in the present paper, the main object of which has been a popular exposition of the general physical laws which must be obeyed by the builder, or engineer, who desires to construct domestic or other buildings that will satisfy the wants of intelligent people.

The mischievous action of freezing water is not confined to the pipes that are constructed to receive or convey it. Wherever water may be, if that water freezes, it must expand in the degree and with the force already described. If it penetrates stone or brick, or mortar or stucco, and freezes therein, one of two things must occur—either the superfluous ice must exude at the surface or to neighboring cavities, or the saturated material must give way, and split or crumble according to the manner and degree of penetration. To understand this, the reader must remember what I stated about the little-understood *viscosity* of ice, as well as its expansion at the moment of freezing.

Bricks are punished, but not so severely as might be anticipated, seeing how porous are some of the common qualities, especially those used in London. They are so amply porous that the water not only finds its way into them, but the pores are big enough and many enough for the ice to demonstrate its viscosity by squeezing out and displaying its crystalline structure in the form of snow-like efflorescence on the surface. This may have been observed by some of my readers during a severe frost. It is commonly confounded with the hoar-frost that whitens the roofs of houses, but which is very rarely deposited on perpendicular wall faces.

The mortar most liable to suffer is that which is porous and pulverulent within, but has been cleverly faced or pointed with a crust of more compact material. This outer film prevents the exuding of the expanding ice crystals, is thrust forth bodily, and retained by ice-cement during the frost, but it falls in scales when this temporary binding material thaws. Mortar that is compact throughout does not suffer to any appreciable extent. This is proved by the condition of the remains of Roman brick-work that still exist in Britain and other parts of Europe. Some of the old shingle walls at Brighton and other parts of the south coast, where the chalk for lime-burning was at the builder's feet, and where his mortar is so thickly laid between the irregular masses of flint, also show the possible duration of good mortar. The jerry builder's mortar, made of the riddlings of burnt clay ballast and dust-hole refuse just flavored with lime, crumbles immediately, because these materials do not combine with the lime as fine siliceous sand gradually does, to form an impermeable glassy silicate.

Stucco is punished by two distinct modes of action. The first is where the surface is porous, and the water permeates accordingly and freezes. This, of course, produces superficial crumbling, which should not occur at all upon good material protected by suitable paint. The other case, very deplorable in many instances, is where the water finds a space between the inner surface of the stucco and the outer surface of the material upon which it is laid. This water, when frozen, of course, expands, and wedges away the stucco bodily, causing it to come down in masses at the thaw. This, however, only occurs after severe frosts, as the ordinary mild frosts of our favored climate seldom endure long enough to penetrate to any notable depth of so bad a conductor as stone or stucco. It is worthy of note that water is a still worse conductor than stone.

Building stones are so various both in chemical composition and mechanical structure that the action of freezing water is necessarily as varied as the nature of the material. The highly siliceous granites (or, rather, porphyries that commonly bear the name of granite) are practically im-

permeable to water so long as they are free from any chemical decomposition of their feldspathic constituents; but when we come to sandstones and limestones, or intermediate material, very wide differences prevail.

The possible width of this difference is shown in the behavior of the unselected material in its natural home. Certain cliffs and mountains have stood for countless ages almost unchanged by the action of frost; others are breaking up with astonishing rapidity in spite of apparent solidity of structure. The Matterhorn, or Mont Cervin, one of the most gigantic of the giant Alps, 15,200 feet high, is rendered especially dangerous to ambitious climbers by the continual crashing down of fragments that are loosened when the summer sun melts the ice that first separated and then for awhile held them in their original places. All the glaciers of the Alps are more or less streaked with "moraines," which are fragments of the mountains that freezing water has detached.

Our stone buildings would suffer proportionally if some selection of material were not made. Generally speaking, this selection is based upon the experience of previous practical trials. Certain quarries are known to have supplied good material of a certain character, and this quarry has, therefore, a reputation which is usually of no small value to its fortunate owner. Other quarries are opened in the neighborhood wherever the rock resembles that of the tested quarry.

Sometimes, however, materials are open for selection that have not been so well tested, and a method of testing which is more expeditious and less expensive than constructing a building and watching the result, is very desirable. The subject of testing building materials in special reference to their resistance of frost was brought before the Academy of Science of Paris by M. Brard some years since.

In his preliminary experiments he used small cubes of the stone to be tested, soaked them in water, and then exposed them to the air in frosty weather, or subjected them to the action of freezing mixtures. Afterward he found that by availing himself of the expansive force which certain saline solutions exert at the moment of crystallization, he could conveniently imitate the action of freezing without the aid of natural or artificial frost. Epsom salts, nitre, alum, sulphate of iron, Glauber's salts, etc., were tried. The last-named, Glauber's salt (or sulphate of soda), which is very cheap, was found to be the best for the purpose.

His method of applying the test is as follows: Cut the specimens into two-inch cubes, with flat sides and sharp edges and corners, mark each specimen with a number, either by ink or scratching, and enter in a book all particulars concerning it. Make a saturated solution of the sulphate of soda in rain or distilled water, by adding the salt until no more will dissolve; perfect saturation being shown by finding, after repeated stirring, that a little of the salt remains at the bottom an hour or two after the solution was made. Heat this solution in a suitable vessel, and when it boils put in the marked specimens one by one, and keep them immersed in the boiling solution for half an hour. Take out the specimens separately and suspend them by threads, each over a separate vessel containing some of the liquid in which they were boiled, but which has been carefully strained to free it from any solid particles. In the course of a day or two, as the cubes dry, they will become covered with an efflorescence of snow-like crystals; wash these away by simply plunging the specimen into the vessel below, and repeat this two or three times daily for four or five days or longer. The most suitable vessel for the purpose is a glass "beaker," sold by vendors of chemical apparatus.

In comparing competing samples, be careful to treat all alike, *i.e.*, boil them together in the same solution,

and dip them an equal number of times at equal intervals.

Having done this, the result is now to be examined. If the stone is completely resistant the cube will remain smooth on its surfaces and sharp at its edges and corners, and there will be no particles at the bottom of the vessel. Otherwise, the inability of the stone to resist the test will be shown by the disfigurement of the cube or the small particles wedged off and lying at the bottom of the liquid. Care must be taken not to confound these with crystals of the salt which may also be deposited. These crystals are easily removed by adding a little more water or warming the solution.

For strict comparison the fragments thus separated should be weighed in a delicate balance, such as is used in chemical analysis.

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## FIRE-CLAY AND ANTHRACITE.

For household fireplaces, whether open or closed, these may be regarded as the material and the fuel of the future, and should be more generally and better understood than they are.

The merits of fire-clay were fully appreciated and described nearly a hundred years ago by that very remarkable man, Benjamin Thompson, Count of Rumford. Any sound scientific exposition of the relative value of fire-clay and iron as fireplace materials can be little more or less than a repetition of what he struggled to teach at the beginning of the present century.

It is impossible to fairly understand this subject unless we start with a firm grasp of first principles. The business before us is to get as much heat as possible from fuel burning in a certain fashion, and to do this with the smallest possible emission of smoke.

Substances that are hotter than their surroundings communicate their excess of temperature in three different ways: 1st, by *Conduction;* 2d, by *Convection;* 3d, by *Radiation.* All of these are operating in every form of fireplace, but in very different proportions according to certain variations of construction.

To demonstrate the conduction of heat, hold one end of a pin between the finger and thumb, and the other end in the flame of a candle. The experiment will terminate very speedily. Then take a piece of a lucifer match of the same length as the pin, and hold that in the candle. This may become red hot and flaming without burning the fingers, as the pin did at a much lower temperature. It matters not whether the pin be held upward, downward, or sideway, the heat will travel throughout its substance, and this sort of traveling is called "conduction," and the pin a "conductor" of heat. The conducting power of different substances varies greatly, as the above experiment shows. Metals generally are the best conductors, but they differ among themselves; silver is the best of all, copper the next. Calling (for comparison sake) the conductivity of silver 1000, that of copper is 736, gold 532, brass 236, iron 119, marble and other building stones 6 to 12, porcelain 5, ordinary brick earth only 4, and fire-brick earth less than this. Thus we may at once start upon our subject, with the practical fact that iron conducts heat thirty times more readily than does fire-brick.

*Convection* is different from conduction, inasmuch as it is effected by the movements of the something which has been heated by contact with something else. Water is a very bad conductor of heat, much worse than fire-brick, and yet, as we all know, heat is freely transmitted by it, as when we boil water in a kettle. If, however, we placed the water in a fire-clay kettle, and applied the heat at the top we should have to wait for our tea until to-morrow or the next day. When the heat is applied below, the hot metal of the kettle heats the bot-

tom film of water by *direct contact;* this film expands, and thus, being lighter, rises through the rest of the water, heating other portions by contact as it meets them, and so on throughout. The heat is thus conveyed, and the term "convection" is based on the view that each particle is a carrier of heat as it proceeds. Air conveys heat in the same manner; so may all gases and liquids, but no such convection is possible in solids. The common notion that "heat ascends" is based on the well-known facts of convection. It is the heated gas or liquid that really ascends. No such preference is given to an upward direction, when heat is conducted or radiated.

*Radiation* is a flinging off of heat in all directions by the heated body. Radiation from solids is mainly superficial, and it depends on the nature of the heated surface. The rougher and the more porous the surface of a given substance the better it radiates. Bright metals are the worst radiators; lampblack the best, and fire-brick nearly equal to it. To show the effect of surface, take three tin canisters of equal size, one bright outside, the second scratched and roughened, the third painted over with a thin coat of lampblack. Fill each with hot water of the same temperature, and leave them equally exposed. Their rates of radiation will then be measurable by their rates of cooling. The black will cool the most rapidly, the rough canister next, and the bright one the slowest.

Radiant heat may be reflected like light from bright surfaces, the reflecting substance itself becoming heated in a proportion which diminishes just as its reflecting powers increase. Good reflectors are bad radiators and bad absorbers of heat, and the power of *absorbing* heat, or becoming superficially hot when exposed to radiant heat, is exactly proportionate to radiating efficiency.

Fire-clay is a good absorber of radiant heat, *i.e.*, it becomes readily heated when near to hot coals or flames, without requiring actual contact with them. It is an equally good radiator.

Let us now apply these facts to fire-clay in fireplaces, beginning with ordinary open grates used for the warming of apartments; first supposing that we have an ordinary old-fashioned grate all made of iron—front, sides, and back, as well as bars, and next that we have another of similar form and position, but all the fire-box and the back and cheeks of the grate made of fire-clay.

It is evident that the fire-clay not in actual contact with the coals, but near to them, will absorb more heat than the iron, and thus become hotter. Even at the same temperature it will radiate much more heat than iron, but being so much hotter this advantage will be proportionately increased. An open fireplace lined throughout with fire-clay thus throws into the room a considerable amount of its own radiation in addition to that thrown out from the coal.

But what becomes of this portion of the heat when the fireplace is all of metal? It is carried up the chimney by convection, for the metal, while it parts with less heat by radiation, gives up more to the air by direct contact. Therefore, if we must burn our coals inside the chimney, we lose less by burning them in a fire-clay box than in a metal box.

Count Rumford demonstrates this, and described the best form of open firegrate that can be placed in an ordinary English hole-in-the-wall fireplace. The first thing to be done, according to his instructions, is to brick up your large square fireplace recess, so that the back of it shall come forward to about 4 in. from the front inside face of the chimney, thus contracting the *throat* of the chimney, just behind the mantle, to this small depth (Rumford's device for sweeping need not be here described). The sides or "covings" of this shallowed recess are now to be sloped inward so that each one shall horizontally be at an angle of 135 deg. to the plane

of this new back, and meet it at a distance of six or more inches apart, according to the size of grate required. The covings will thus spread out at right angles with each other, and leave an annular opening to be lined with fire-brick, and run straight up to the chimney. The fire-bars and grate bottom to be simply let into this as far forward as possible.

By this simple arrangement we get a firegrate with a narrow flat back and out-sloping sides; all these three walls are of fire-brick; the back radiates perpendicularly across the room; and the sloping sides radiate outward, instead of merely across the fire from one to the other, as when they are square to the walls.

At Rumford's time our ordinary fireplaces were square recesses; now we have adopted something like his suggestion in the sloping sides of our register grates, and we bring our fireplaces forward. We have gone backward in material, by using iron, but this, after all, may be merely due to the ironmongery interest overpowering that of the bricklayers. The preponderance of this interest in the South Kensington Exhibition may account for the fact that Rumford's simple device was not to be seen in action there. It could not pay anybody to exhibit such a thing, as nobody can patent it, and nobody can sell it. I have seen the Rumford arrangement carried out in office fireplaces with remarkable success. To apply it anywhere requires only an intelligent bricklayer, a few bricks, and some iron bars.

Although nobody exhibited this, a very near approach to it was described in an admirable lecture delivered at South Kensington, by Mr. Fletcher, of Warrington. In one respect Mr. Fletcher goes further than Count Rumford in the application of fire-clay. He makes the bottom of the firebox of a slab of fire-clay instead of ordinary iron fire-bars. This demands a little more trouble and care in lighting the fire, owing to the absence of bottom-draught, but when the fire is well started the advantages of this further encasing in fire-clay are considerable. They depend upon another effect of the superior radiant and absorbent properties of fire-clay that I will now explain.

So far, I have only described the beneficial effect of its radiation on the room to be heated, but it performs a further duty inside the fireplace itself. Being a bad conductor, it does not readily carry away the heat of the burning coal that rests upon it, and being also an excellent absorber, it soon becomes very hot—*i.e.*, superficially hot, or hot where its heat is effective. This action may be seen in a common register stove with fire-clay back and iron sides. When the fire is brisk the back is visibly red hot, while the sides are still dull. If, after such a fire has burnt itself out, we carefully examine the ashes, there will be found more fine dust in contact with the fire-brick than with the iron—*i.e.*, evidence of more complete combustion there; and one of the advantages justly claimed by Mr. Fletcher is, that with his solid fire-clay bottom there will be no unburnt cinders—nothing left but the incombustible mineral ash of the coal. Economy and abatement of smoke are the necessary concomitants of such complete combustion.

A valuable "wrinkle" was communicated by Mr. Fletcher. The powdered fire-clay that is ordinarily sold is not easily applied on account of its tendency to crumble and peel off the back and sides of the stove after the first heating. In order to overcome this, and obtain a fine compact lining, Mr. Fletcher recommends the mixing of the fire-clay powder with a solution of water-glass (silicate of soda) instead of simple water. It acts by forming a small quantity of glassy silicate of alumina, which binds the whole of the clay together by its fusion when heated.

Londoners, and, in fact, Englishmen generally, have hitherto regarded anthracite as a museum min-

eral and a curiosity, rather than an everyday coal-scuttle commodity. If it is to be the fuel of the future, it is very desirable that we should all know something about its merits and demerits, as well as the possibilities of supply.

Anthracite is a natural coke. From its position in the earth, and its relations to bituminous coal, as well as from its composition, we are justified in regarding it as a coal that was originally bituminous, but which has been altered by heat, acting under great pressure. In the great coal-field of South Wales, to which we must look for our main supply of anthracite, we are able to trace the action of heat in producing a whole series of different classes of coal in a single seam, which at one part is highly bituminous—soft, flaming coal, like the Wall-send, then it becomes harder and less bituminous, then semi-bituminous "steam coal," then less and less flaming, until at last we have the hard shiny form of purely carbonaceous coal, that may be handled without soiling the fingers, and which burns without flame, like coke or charcoal. This change proceeds as the seam extends from the east towards the west. In some places the coal at the base of a hill may be anthracite, while that on the outcrop above it may be bituminous.

An artificial anthracite may be made by heating coal in a closed vessel of sufficient strength to resist the expansion of the gases that are formed. It differs from coke in being compact, is not porous; and therefore, of course, much denser, a given weight occupying less space.

That we Englishmen should be about the last of all the coal-using peoples to apply anthracite to domestic purposes is a very curious fact, but so it is. In America it is the ordinary fuel, and this is the case in all other countries where it is obtainable at the price of bituminous coal. Our perversity in this respect shows out the more strikingly when we go a little further into the subject by comparing the two classes of coal in reference to our methods of using them, and when we consider the fact that our South Wales anthracite is far superior to the American.

Our open fires only do their small fraction of useful work by radiation. Their convection is all up the chimney. Such being the case, and we being theoretically regarded as rational beings, it might be supposed that for our national and especially radiating fireplaces we should have selected a coal of especial radiating efficiency, but, instead of this, we do the opposite. The flaming coal is just that which flings the most heat up the chimney, and the least into the room, and, as though we were all struggling to destroy as speedily as possible the supposed physical basis of our prosperity, we select that coal which in our particular fireplaces burns the most wastefully. If we had closed iron stoves with long stove-pipes in the room, giving to the air the heat they had obtained by the convective action of the flame and smoke, there might be some reason for using the flaming coal, as the flame would thereby do useful work, but, as it is, we stubbornly persist in using only the radiated heat, and at the same time select just the coal which supplies the smallest quantity of what we require.

No scientific dissertation is necessary to prove the superior radiating power of an anthracite fire to anybody who has ever stood in the front of one. This is most strikingly demonstrated by those grates that stand well forward, and are kept automatically filled with the radiant-carbon.

Let us now see *why* anthracite is a better radiator than bituminous coal. This is due to its chemical composition. Of all the substances that we have upon the earth carbon in its ordinary black form is the best radiator. Anthracite contains from 90 to 94 per cent. of pure carbon, bituminous coal from 70 to 85, and much of this being combined with hydrogen burns away as flame,

On a rough average we may say that the fixed or solid carbon capable of burning with a smokeless flameless glow, amounts to 65 per cent. in ordinary British bituminous coal, against an average of 92 per cent. in British anthracite. The advantages of anthracite as a fuel for open radiating grates are nearly in the proportion of these figures. Besides this it contains about half the quantity of ash. Thus we see that from a purely selfish point of view, and quite irrespective of our duty to our fellow-citizens as regards polluting the atmosphere, anthracite is preferable to ordinary coal on economical grounds, supposing we can obtain it at the same price as bituminous coal, which is now the case.

Another great advantage of anthracite is its cleanliness. It may be picked up in the fingers without soiling them, and it is similarly cleanly throughout the house. It produces no "blacks," no grimy dust, and if it were generally in use throughout London one half of the house-cleaning would be saved. White curtains, blinds, etc., might hang quite four times as long, and then come down not half so dirty as now. The saving in soap alone, without counting labor, would at once return a handsome percentage on the capital outlay required for reconstructing all our fireplaces.

Let us now look on the other side, and ask what are the disadvantages of anthracite, and why is it not at once adopted by everybody? There is really only one disadvantage, viz., the greater difficulty of starting an anthracite fire. Practically this is considerable, seeing that laziness is universal and ever ready to find excuses when an innovation is proposed that stands in its way. To light an anthracite fire in an ordinary fireplace the bellows are required unless a specially suitable draught or fire-lighter is used. Some recommend that an admixture of bituminous coal should be used to start it, but this is a feeble device calculated to lead to total failure, seeing that the sole originator and sustainer of our ordinary use of bituminous coal is domestic ignorance and indolence, and if both kinds of coal are kept in a house a common English servant will stubbornly use the easy lighting kind, and solemnly assert that the other cannot be used at all. The only way to deal with this obstacle, the human impediment, is to say, "This you must use, or go." This is strictly just, as a simple enforcement of duty.

At the same time some help should be supplied in the way of artificial modes of creating a draught in starting an anthracite fire. This may be done by temporarily closing the front of the fire by a "blower," or better still by selecting one of the grates specially devised for burning anthracite of which so many now are made. Another and rather important matter is to obtain the anthracite in suitable condition. It is a very hard coal, too hard to be broken by the means usually at hand in ordinary houses. For domestic purposes it should always be delivered broken up of suitable size, from that of an egg to a cocoa-nut. For furnaces, of course, large lumps are preferable.

Then, again, anthracite must not be stirred and poked about; once fairly started it burns steadily and brightly, demanding only a steady feeding. The best of the special grates are more or less automatic in the matter of feeding, and thus the trouble of lighting is fully compensated by the absence of any further trouble.

As regards the supply. This for London and the greater part of England will doubtless be derived from the great coal-field of South Wales. The total quantity of available coal in this region after deducting the waste in getting, was estimated by the Government Commissioners at 32,456 millions of tons. It is very difficult or impossible to correctly estimate the proportion of anthracite in this, but supposing it to be one-tenth of true anthracite it gives us

3245 millions of tons, or about enough for the domestic supply of the whole country during 100 years, assuming that it shall be used less wastefully than we are now using bituminous coal, which would certainly be the case. But, including the imperfect anthracite, the quantity must be far larger than this, and we have to add the other sources of anthracite.

We need not, therefore, have any present fear of insufficient supply; probably before the 100 years are ended we shall find other sources of anthracite, or even have become sufficiently civilized to abolish altogether our present dirty devices, and to adopt rational methods of warming and ventilating our houses. When we do this any sort of coal may be used.

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## COUNT RUMFORD'S COOKING-STOVES.

In the preceding chapter I described Count Rumford's modification of the English open firegrate which eighty years ago was offered to the British nation without any patent or other restrictions. Its non-adoption I believe to be mainly due to this—it was nobody's monopoly, nobody's business to advertise it, and, therefore, nobody took any further notice of it; especially as it cannot be made and sold as a separate portable article.

An ironmonger or stove-maker who should go to the expense of exhibiting Rumford's simple structure of fire-bricks and a few bars described in the last chapter, would be superseding himself by teaching his customers how they may advantageously do without him.

The same remarks apply to his stoves for cooking purposes. They are not iron boxes like our modern kitcheners, but are brick structures, matters of masonry in all but certain adjuncts, such as bars, fire-doors, covers, oven-boxes, etc., which are very simple and inexpensive. Even some of Rumford's kitchen utensils, such as the steamers, were cheaply covered with wood, because it is a bad conductor, and therefore wastes less heat than an iron saucepan lid.

Rumford was no mere theorist, although he contributed largely to pure science. His greatest scientific discoveries were made in the course of his persevering efforts to solve practical problems. I must not be tempted from my immediate subject by citing any examples of these, but may tell a fragment of the story of his work so far as it bears upon the subject of cooking-ranges.

He began life as a poor schoolmaster in New Hampshire, when it was a British colony. He next became a soldier; then a diplomatist; then in strange adventurous fashion he traveled on the Continent of Europe, entered the Bavarian service and began his searching reform of the Bavarian army by improving the feeding and the clothing of the men. He became a practical working cook, in order that they should be supplied with good, nutritious, and cheap food.

But this was not all. He found Munich in a most deplorable condition as regards mendicity; and took in hand the gigantic task of feeding, clothing, and employing the overwhelming horde of paupers, doing this so effectually that he made his "House of Industry" a true workhouse; it paid all its own expenses, and at the end of six years left a net profit of 100,000 florins.

I mention these facts in confirmation of what I said above concerning his practical character. Economical cookery was at the root of his success in this maintenance of a workhouse without any poor-rates.

After doing all this he came to England, visited many of our public institutions, reconstructed their fire-places, and then cooked dinners in presence of distinguished witnesses, in order to show how little need be expended on fuel, when it is properly used.

At the Foundling Institution in London he roasted 112 lbs. of beef with 22 lbs. of coal, or at a cost of less than threepence. The following copy of certificate, signed by the Councilor of War, etc., shows what he did at Munich: "We whose names are underwritten certify that we have been present frequently when experiments have been made to determine the expense of fuel in cooking for the poor in the public kitchen of the military workhouse at Munich, and that when the ordinary dinner has been prepared for 1000 persons, the expense for fuel has not amounted to quite 12 kreutzers." Twelve kreutzers is about 4½*d.* of our money. Thus only 1–50th of a farthing was expended on cooking each person's dinner, although the peas which formed the substantial part of the soup required five hours' boiling. The whole average daily fuel expenses of the kitchen of the establishment amounted to 1–20th of a farthing for each person, using wood, which is much dearer than coal. At this rate, *one ton of wood should do the cooking for ten persons during two years and six days, or one ton of coal would supply the kitchen of such a family three and a half years.*

The following is an abstract of the general principles which he expounds for the guidance of all concerned in the construction of cooking-stoves.

1. All cooking fires should be enclosed.

2. Air only to be admitted from below and under complete control. All air beyond what is required for the supply of oxygen "is a thief."

3. All fireplaces to be surrounded by non-conductors, *brickwork, not iron.*

4. The residual heat from the fireplace to be utilized by long journeys in returning flues, and by *doing the hottest work first.*

5. Different fires should be used for different work.

The first of these requirements encounters one of our dogged insular prejudices. The slaves to these firmly believe that meat can only be roasted by hanging it up to dry in front of an open fire; their savage ancestors having held their meat on a skewer or spit over or before an open fire, modern science must not dare to demonstrate the wasteful folly of the holy sacrifice. Their grandmothers having sent joints to a bakehouse, where other people did the same, and having found that by thus cooking beef, mutton, pork, geese, etc., some fresh, and some stale, in the same oven, the flavors became somewhat mixed, and all influenced by sage and onions, these people persist in believing that meat cannot be roasted in any kind of closed chamber.

Rumford proved the contrary, and everybody who has fairly tried the experiment knows that a properly ventilated and properly heated roasting oven produces an incomparably better result than the old desiccating process.

Rumford's roaster was a very remarkable contrivance, that seems to have been forgotten. It probably demands more intelligence in using it than is obtainable in a present-day kitchen. When the School Boards have supplied a better generation of domestic servants we may be able to restore its use.

It is a cylindrical oven with a double door to prevent loss of heat. In this the meat rests on a grating over a specially constructed gravy and water dish. Under the oven are two "blow-pipes," *i.e.*, stout tubes standing just above the fire so as to be made red hot, and opening into the oven at the back, and above the fireplace in front, where there is a plug to be closed or open as required. Over the front part of the top of the oven is another pipe for carrying away the vapor. It is thus used:—The meat is first cooked in an atmosphere of steam formed by the boiling of water placed in the bottom of the double dish, over which the meat rests. When by this means the meat has been raised throughout its whole thickness to the temperature at which its albumen coagulates, the plugs are removed from the blow-pipes, and *then* the special action of

roasting commences by the action of a current of superheated air which enters below and at the back of the oven, travels along and finds exit above and in front, by the steam-pipe before named.

The result is a practical attainment of theoretical perfection. Instead of the joint being dried and corticated outside, made tough, leathery, and flavorless to about an inch of depth, then fairly cooked an inch further, and finally left raw, disgusting, and bloody in the middle, as it is in the orthodox roasting by British cooks, the whole is uniformly cooked throughout without the soddening action of mere boiling or steaming, as the excess of moisture is removed by the final current of hot dry air thrown in by the blow-pipes, which at the same time give the whole surface an uniform browning that can be regulated at will without burning any portion or wasting the external fat.

Rumford's second rule, that air be admitted only from below, and be limited to the requirements, is so simple that no comment upon it is needed. Although we have done so little in the improvement of domestic fireplaces, great progress has been made in engine furnaces, blast furnaces, and all other fireplaces for engineering and manufacturing purposes. Every furnace engineer now fully appreciates Rumford's assertion that excess of cold air is a thief.

The third rule is one which, as I have already stated, stands seriously in the way of any commercial "pushing" of Rumford's kitchen ranges. Those which he figures and describes are all of them masonic structures, not ironmongery; the builder must erect them, they cannot be bought ready-made; but, now that public attention is roused, I believe that any builder who will study Rumford's plans and drawings, which are very practically made, may do good service to himself and his customers by fitting up a few houses with true Rumford kitcheners, and offering to reconstruct existing kitchen ranges, especially in large houses.

The fourth rule is one that is sorely violated in the majority of kitcheners, and without any good reason. The heat from the fire of any kitchener, whether it be of brick or iron, should first do the work demanding the highest temperature, viz. roasting and baking, then proceed to the boiler or boilers, and after this be used for supplying the bed rooms and bath room and the housemaid, etc., with hot water for general use, as Rumford did in his house at Brompton Row, where his chimney terminated in metal pipes that passed through a water-tank at the top of the house.

Linen-closets may also be warmed by this residual heat.

The fifth rule is also violated to an extent that renders the words uttered by Rumford nearly a century ago as applicable now as then. He said, "Nothing is so ill-judged as most of those attempts that are frequently made by ignorant projectors *to force the same fire to perform different services at the same time.*"

Note the last words, "same time." In the uses above mentioned the heat does different work successively, which is quite different from the common practice of having flues to turn the flame of one fire in opposite directions, to split its heat and make one fireplace appear to do the work of two.

Every householder knows that the kitchen fire, whether it be an old-fashioned open fireplace, or a modern kitchener of any improved construction, is a very costly affair. He knows that its wasteful work produces the chief item of his coal bill, but somehow or other he is helpless under its infliction. If he has given any special attention to the subject he has probably tried three or four different kinds without finding any notable relief. Why is this? I venture to make a reply that will cover 90 per cent., or probably 99 per cent., of these cases, viz., that he has never considered the

main source of waste, which Rumford so clearly defines as above, and which was eliminated in all the kitchens that he erected.

Let us suppose the case of a household of ten persons, but which in the ordinary course of English hospitality *sometimes* entertains twice that number. What do we find in the kitchen arrangements? Simply that there is one fireplace suited for the maximum requirements, *i.e.*, sufficient for twenty, even though that number may not be entertained more than half a dozen times in the course of a year. To cook a few rashers of bacon, boil a few eggs, and boil a kettle of water for breakfast, a fire sufficient to cook for a dinner party of twenty is at work. This is kept on all day long, because it is just possible that the master of the house may require a glass of grog at bedtime. There may be dampers and other devices for regulating this fire, but such regulation, even if applied, does very little so long as the capacity of the grate remains, and as a matter of ordinary fact the dampers and other regulating devices are neglected altogether; the kitchen fire is blazing and roaring to waste from 6 or 7 A.M. to about midnight, in order to do about three hours and a half work, *i.e.*, the dinner for ten, and a nominal trifle for the other meals.

In Rumford's kitchens, such as those he built for the Baron de Lerchenfeld and for the House of Industry at Munich, the kitchener is a solid block of masonry of work-bench height at top, and with a deep bay in the middle, wherein the cook stands surrounded by his boilers, steamers, roasters, ovens, etc., all within easy reach, each one supplied by its own separate fire of very small dimensions, and carefully closed with non-conducting doors. Each fire is lighted when required, charged with only the quantity of fuel necessary for the work to be done, and then extinguished or allowed to die out.

It is true that Rumford used wood, which is more easily managed in this way than coal. If we worked as he did, we might use wood likewise, and in spite of its very much higher price do our cooking at half its present cost. This would effect not merely "smoke abatement" but "smoke extinction" so far as cooking is concerned. But the lighting of fires is no longer a troublesome and costly process as in the days of halfpenny bundles of firewood. To say nothing of the improved fire-lighters, we have gas everywhere, and nothing is easier than to fix or place a suitable Bunsen or solid flame burner under each of the fireplaces (an iron gas-pipe, perforated *below* to avoid clogging, will do), and in two or three minutes the coals are in full blaze; then the gas may be turned off. The writer has used such an arrangement in his study for some years past, and starts his fire in full blaze in three minutes quite independent of all female interference.

I have no doubt that ultimately gas will altogether supersede coal for cooking; but this and all other scientific improvements in domestic comfort and economy must be impossible with the present generation of uneducated domestics, whose brains (with few exceptions) have become torpid and wooden from lack of systematic exercise during their period of growth.

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## THE AIR OF STOVE-HEATED ROOMS.

WHATEVER opinions may be formed of the merits of the exhibits at South Kensington, one result is unquestionable—the exhibition itself has done much in directing public attention to the very important subject of economizing fuel and the diminution of smoke. We sorely need some lessons. Our national progress in this direction has been simply contemptible, so far as domestic fire-places are concerned.

To prove this we need only turn back to the essays of Benjamin

Thompson, Count of Rumford, published in London just eighty years ago, and find therein nearly all that the Smoke Abatement Exhibition *ought* to teach us, both in theory and practice—lessons which all our progress since 1802, plus the best exhibits at South Kensington, we have yet to learn.

This small progress in domestic heating is the more remarkable when contrasted with the great strides we have made in the construction and working of engineering and metallurgical furnaces, the most important of which is displayed in the Siemens regenerative furnace. A climax to this contrast is afforded by a speech made by Dr. Siemens himself, in which he defends our domestic barbarisms with all the conservative inconvincibility of a born and bred Englishman, in spite of his German nationality.

The speech to which I refer is reported in the "Journal of the Society of Arts," December 9, 1881, and contains some curious fallacies, probably due to its extemporaneous character; but as they have been quoted and adopted not only in political and literary journals, but also by a magazine of such high scientific standing as "Nature" (see editorial article January 5, 1882, p. 219), they are likely to mislead many.

Having already, in my "History of Modern Invention, etc.," and in other places, expressed my great respect for Dr. Siemens and his benefactions to British industry, the spirit in which the following plain-spoken criticism is made will not, I hope, be misunderstood either by the readers of "Knowledge" or by Dr. Siemens himself.

I may further add that I am animated by a deadly hatred of our barbarous practice of wasting precious coal by burning it in iron fire-baskets half buried in holes within brick walls, and under shafts that carry 80 or 90 per cent. of its heat to the clouds; that pollute the atmosphere of our towns, and make all their architecture hideous; that render scientific and efficient ventilation of our houses impossible; that promote rheumatism, neuralgia, chilblains, pulmonary diseases, bronchitis, and all the other "ills that flesh is heir to" when roasted on one side and cold-blasted on the other; that I am so rabid on this subject, that if Dr. Siemens, Sir F. Bramwell, and all others who defend this English abomination, were giant windmills in full rotation, I would emulate the valor of my chivalric predecessor, whatever might be the personal consequences.

Dr. Siemens stated that the open fireplace "communicates absolutely no heat to the air of the room, because air, being a perfectly transparent medium, the rays of heat pass clean through it."

Here is an initial mistake. It is true that air which has been artificially deprived of *all* its aqueous vapor is thus completely permeable by heat rays, but such is far from being the case with the water it contains. This absorbs a notable amount even of bright solar rays, and a far greater proportion of the heat rays from a comparatively obscure source, such as the red-hot coals and flame of a common fire. Tyndall has proved that 8 to 10 per cent. of all the heat radiating from such a source as a common fire is absorbed in passing through only 5 feet of air in its ordinary condition, the variation depending upon its degree of saturation with aqueous vapor.

Starting with the erroneous assumption that the rays of heat pass "clean through" the air of the room, Dr. Siemens went on to say that the open fireplace "gives heat only by heating the walls, ceiling, and furniture; and here is the great advantage of the open fire;" and, further, that "if the air in the room were hotter than the walls, condensation would take place on them, and mildew and fermentation of various kinds would be engendered; whereas, if the air were cooler than the walls, the latter must be absolutely dry."

Upon these assumptions, Dr. Siemens condemns steam pipes and stoves, hot-air pipes, and all other methods of directly heating the *air* of apartments, and thereby making it warmer than were the walls, the ceiling, and furniture when the process of warming commenced. It is quite true that stoves, stove-pipes, hot-air pipes, steam pipes, etc., do this: they raise the temperature of the air directly by *convection; i. e.*, by warming the film of air in contact with their surfaces, which film, thus heated and expanded, rises toward the ceiling, and, on its way, warms the air around it, and then is followed by other similarly-heated ascending films. When we make a hole in the wall, and burn our coals within such cavity, this convection proceeds up the chimney in company with the smoke.

But is Dr. Siemens right in saying that the air of a room, raised by convection above its original temperature, and above that of the walls, deposits any of its moisture on these walls? I have no hesitation in saying very positively that he is clearly and demonstrably wrong; that no such condensation can possibly take place under the circumstances.

Suppose, for illustration sake, that we start with a room of which the air and walls are at the freezing point 32° F., before artificial heating (any other temperature will do), and, to give Dr. Siemens every advantage, we will further suppose that the air is fully saturated with aqueous vapor, *i.e.*, just in the condition at which some of its water might be condensed. Such condensation, however, can only take place by cooling the air *below* 32°, and unless the walls or ceiling or furniture are capable of doing this they cannot receive any moisture due to such condensation, or, in other words, they must fall below 32° in order to obtain it by cooling the film in contact with them. Of course Dr. Siemens will not assert that the stoves or steam-pipes (enclosing the steam, of course), or the hot air or hot water pipes, will lower the *absolute* temperature of the walls by heating the air in the room.

But if the air is heated more rapidly than are the walls, etc., the *relative* temperature of these will be lower. Will condensation of moisture *then* follow, as Dr. Siemens affirms? Let us suppose that the air of the room is raised from 30° to 50° *by convection purely;* reference to tables based on the researches of Regnault, shows that at 32° the quantity of vapor required to saturate the air is sufficient to support a column of 0·182 inch of mercury, while at 50° it amounts to 0·361, or nearly double. Thus the air, instead of being in a condition of giving away its moisture to the walls, has become thirsty, or in a condition to *take moisture away from them* if they are at all damp. This is the case whether the walls remain at 32° or are raised to any higher temperature short of that of the air.

Thus the action of close stoves and of hot surfaces or pipes of any kind is exactly the opposite of that attributed to them by Dr. Siemens. They dry the air, they dry the walls, they dry the ceiling, they dry the furniture and everything else in the house.

In *our* climate, especially in the infamous jerry-built houses of suburban London, this is a great advantage. Dr. Siemens states his American experience, and denounces such heating by convection because the close stoves *there* made him uncomfortable. This was due to the fact that the winter atmosphere of the United States is very dry, even when at zero. But air, when raised from 0° to 60°, acquires about twelve times its original capacity for water. The air thus simply heated is desiccated, and it desiccates everything in contact with it, especially the human body. The lank and shriveled aspect of the typical Yankee is, I believe, due to this. He is a desiccated Englishman,

and we should all grow like him if our climate were as dry as his.* The great fires that devastate the cities of the United States appear to me to be due to this general desiccation of all building materials, rendering them readily inflammable and the flames difficult of extinction.

When an undesiccated Englishman, or a German endowed with a wholesome John Bull rotundity, is exposed to this superdried air, he is subjected to an amount of bodily evaporation that must be perceptible and unpleasant. The disagreeable sensations experienced by Dr. Siemens in the stove-heated railway cars, etc., were probably due to this.

An English house, enveloped in a foggy atmosphere, and encased in damp surroundings, especially requires stove-heating, and the most inveterate worshipers of our national domestic fetish, the open grate, invariably prefer a stove or hot-pipe-heated room, when they are unconscious of the source of heat, and their prejudice hoodwinked. I have observed this continually, and have often been amused at the inconsistency thus displayed. For example, one evening I had a warm contest with a lady, who repeated the usual praises of the cheerful blaze, etc., etc. On calling afterward, on a bitter snowy morning, I found her and her daughters sitting at work in a billiard-room, and asked them why. "Because it is so warm and comfortable." This room was heated by an 8-inch steam-pipe, running around and under the table, to prevent the undue cooling of the india-rubber cushions, and thus the room was warmed from the middle, and equally and moderately throughout. The large reception-room, with blazing fire, was scorching on one side, and freezing on the other, at that time in the morning.

The permeability of ill-constructed iron stoves to poisonous carbonic oxide, which riddles through red-hot iron, is a real evil, but easily obviated by proper lining. The frizzling of particles of organic matter, of which we hear so much, is—if it really does occur—highly advantageous, seeing that it must destroy organic poison-germs.

Under some conditions, the warm air of a room *does* deposit moisture on its cooler walls. This happens in churches, concert-rooms, etc., when they are but occasionally used in winter time, and mainly warmed by animal heat, by congregational emanations of breath-vapor, and perspiration—*i. e.*, with warm air supersaturated with vapor. Also, when we have a sudden change from dry, frosty weather to warm and humid. Then our walls may be streaming with condensed water. Such cases were probably in the mind of Dr. Siemens when he spoke; but they are quite different from stove-heating or pipe-heating, which increases the vapor capacity of the heated air, without supplying the demand it creates.

* In each of my three visits to America I lost about thirty pounds in weight, which I recovered within a few months of my return to the "home country" (of English speaking nations).—RICHARD A. PROCTER.

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## DOMESTIC VENTILATION.

### A LESSON FROM THE COAL-PITS.

WE require in our houses an artificial temperate climate which shall be uniform throughout, and at the same time we need a gentle movement of air that shall supply the requirements of respiration without any gusts, or draughts, or alternations of temperature. Everybody will admit that these are fundamental *desiderata*, but whoever does so becomes thereby a denouncer of open-grate fireplaces, and of every system of heating which is dependent on any kind of stoves with fuel burning in the rooms that are to be inhabited. All such devices concentrate the heat in one part of each room, and demand the admission of cold air from some other part or parts, thereby violating the primary condition of uniform temperature.

The usual proceeding effects a specially outrageous violation of this, as I showed in the last chapter.

I might have added domestic cleanliness among the *desiderata;* but in the matter of fireplaces, the true-born Briton, in spite of his fastidiousness in respect to shirt-collars, etc., is a devoted worshiper of dirt. No matter how elegant his drawing-room, he must defile it with a coal-scuttle, with dirty coals, poker, shovel, and tongs, dirty ash-pit, dirty cinders, ashes, and dust, and he must amuse himself by doing the dirty work of a stoker toward his "cheerful, companionable, pokeable" open fire.

It is evident that, in order to completely fulfill the first-named requirements, we must, in winter, supply our model residence with fresh artificially-warmed air, and in summer with fresh cool air. How is this to be done? An approach to a practical solution is afforded by examining what is actually done under circumstances where the ventilation problem presents the greatest possible difficulties, and where, nevertheless, these difficulties have been effectually overcome. Such a case is presented by a deep coal mine. Here we have a little working world, inhabited by men and horses, deep in the bowels of the earth, far away from the air that must be supplied in sufficient quantities, not only to overcome the vitiation due to their own breathing, but also to sweep out the deadly gaseous emanations from the coal itself.

Imagine your dwelling-house buried a quarter of a mile of perpendicular depth below the surface of the earth, and its walls giving off suffocating and explosive gases in such quantities that steady and abundant ventilation shall be a matter of life or death, and that in spite of this it is made so far habitable that men who spend half their days there retain robust health and live to green old age, and that horses after remaining there day and night for many months actually improve in condition. Imagine, further, that the house thus ventilated has hundreds of small, very low-roofed rooms, and a system of passages or corridors with an united length of many miles, and that its inhabitants count by hundreds.

Such dwellings being thus ventilated and rendered habitable for man and beast, it is idle to dispute the practical possibility of supplying fresh air of any given temperature to a mere box of brick or stone, standing in the midst of the atmosphere, and containing but a few passages and apartments.

The problem is solved in the coal-pit by simply and skillfully controlling and directing the natural movements of unequally-heated volumes of air. Complex mechanical devices for forcing the ventilation by means of gigantic fan-wheels, etc., or by steam-jets, have been tried, and are now generally abandoned. An inlet and an outlet are provided, *and no air is allowed to pass inward or outward by any other course than that which has been pre-arranged for the purposes of efficient ventilation.* I place especial emphasis on this condition, believing that its systematic violation is the primary cause of the bungling muddle of our domestic ventilation.

Let us suppose that we are going to open a coal-pit to win the coal on a certain estate. We first ascertain the "dip" of the seam, or its deviation from horizontality, and then start at the *lowest* part, not, as some suppose, at that part nearest to the surface. The reason for this is obvious on a little reflection, for if we began at the shallowest part of an ordinary water-bearing stratum we should have to drive down under water; but, by beginning at the lowest part and driving upward, we can at once form a "sumpf," or bottom receptacle, to receive the drainage, and from which the accumulated water may be pumped. This, however, is only by the way, and not directly connected with our main subject, the ventilation.

In order to secure this, the modern practice is to sink two pits, "a pair," as they are called, side by side, at any

convenient distance from each other. If they are deep, it becomes necessary to commence ventilation of the mere shafts themselves in the course of sinking. This is done by driving an air-way—a horizontal tunnel from one to the other, and then establishing an "upcast" in one of them by simply lighting a fire there. This destroys the balance between the two communicating columns of air; the cooler column in the shaft without a fire, being heavier, falls against the lighter column, and pushes it up just as the air is pushed up one leg of an U tube when we pour water down the other. Even in this preliminary work, if the pits are so deep that more than one air-way is driven, it is necessary to stop the upper ways and leave only the lowest open, in order that the ventilation shall not take a short and useless cut, as it does up our fireplace openings.

Let us now suppose that the pair of pits are sunk down to the seam, with a further extension below to form the water sumpf. There are two chief modes of working a coal-seam, the "pillar and stall" and the "long wall" or more modern system. For present illustration, I select the latter as the simplest in respect to ventilation. This method, as ordinarily worked, consists essentially in first driving roads through the coal, from the pits to the outer boundary of the area to be worked, then cutting a cross-road that shall connect these, thereby exposing a "long wall" of coal, which, in working, is gradually cut away toward the pits, the roof remaining behind being allowed to fall in.

Let us begin to do this by driving, first of all, two main roads, one from each pit. It is evident that as we proceed in such burrowing, we shall presently find ourselves in a *cul de sac* so far away from the outer air that suffocation is threatened. This will be equally the case with both roads. Let us now drive a cross-cut from the end of each main road, and thus establish a communication from the downcast shaft through its road, then through the drift to the upcast road and pit. But in order that the air shall take this roundabout course, we must close the direct drift that we previously made between the two shafts, or it will proceed by that shorter and easier course. Now, we shall have air throughout both our main roads, and we may drive on further until we are again stopped by approximate suffocation. When this occurs, we make another cross-cut, but in order that it may act, we must stop the first one. So we go on until we reach the working, and then the long wall itself becomes the cross communication, and through this working gallery the air sweeps freely and effectually.

In the above I have only considered the simplest possible elements of the problem. The practical coal-pit in full working has a multitude of intervening passages and "splits," where the main current from the downcast is divided, in order to proceed through the various streets and lanes of the subterranean town as may be required, and these divided currents are finally reunited ere they reach the upcast shaft which casts them all out into the upper air.

In a colliery worked on the pillar and stall system—*i.e.*, by taking out the coal so as to leave a series of square chambers with pillars of coal in the middle to support the roof—the windings of the air between the multitude of passages is curiously complex, and its absolute obedience to the commands of the mining engineer proves how completely the most difficult problems of ventilation may be solved when ignorance and prejudice are not permitted to bar the progress of the practical applications of simple scientific principles.

Here the necessity of closing all false outlets is strikingly demonstrated by the mechanism and working of the "stoppings" or partitions that close all unrequired openings. The air in many pits has to travel several miles in order to get from the downcast to

the upcast shaft, though they may be but a dozen yards apart. (Formerly the same shaft served both for up and down cast, by making a wooden division (a *brattice*) down the middle. This is now prohibited, on account of serious accidents that have been caused by the fracture of the *brattice*.)

But it would not do to carry the coal from the workings to the pit by these sinuous air-courses. What, then, is done? A direct road is made for the coal, but if it were left open, the air would choose it: this is prevented by an arrangement similar to that of canal locks. Valve-doors or "stoppings" are arranged in pairs, and when the "hurrier" arrives with his *corve*, or pit carriage, one door is opened, the other remaining shut; then the *corve* is hurried into the space between the doors, and the entry-door is closed; now the exit-door is opened, and thus no continuous opening is ever permitted.

Only one such opening would derange the ventilation of the whole pit, or of that portion fed by the split thus allowed to escape. It would, in fact, correspond to the action of our open fireplaces in rendering effective ventilation impossible.

The following, from the report of the Lords' Committee on Accidents in Coal Mines, 1849, illustrates the magnitude of the ventilation arrangements then at work. In the Hetton Colliery there were two downcast shafts and one upcast, the former about 12 feet and the latter 14 feet diameter. There were three furnaces at the bottom of the upcast, each about 9 feet wide with about 4 feet length of grate-bars; the depth of the upcast and one downcast 900 feet, and of the other downcast 1056 feet. The quantity of air introduced by the action of these furnaces was 168,560 cubic feet per minute, at a cost of about eight tons of coal per day. The rate of motion of the air was 1097 feet per minute (above 12 miles per hour). This whole current was divided by splitting into 16 currents of about 11,000 cubic feet each per minute, having, on an average, a course of 4¼ miles each. This distance was, however, very irregular—the greatest length of a course being nine-and-one-tenth miles; total length 70 miles. Thus 168,560 cubic feet of air were driven through these great distances at the rate of 12 miles per hour, and at a cost of 8 tons of coal per day.

All these magnitudes are greatly increased in coal-mines of the present time. As much as 250,000 cubic feet of air per minute are now passed through the shafts of one mine.

The problem of domestic ventilation as compared with coal-pit ventilation involves an additional requirement, that of warming, but this does not at all increase the difficulty, and I even go so far as to believe that cooling in summer may be added to warming in winter by one and the same ventilating arrangement. As I am not a builder, and claim no patent rights, the following must be regarded as a general indication, not as a working specification, of my scheme for domestic ventilation and the regulation of home climate.

The model house must have an upcast shaft, placed as nearly in the middle of the building as possible, with which every room must communicate either by a direct opening or through a lateral shaft. An ordinary chimney built in the usual manner is all that is required to form such a main shaft.

There must be no stoves nor any fireplaces in any room excepting the kitchen, of which anon. All the windows must be made to fit closely, as nearly air-tight as possible. No downcast shaft is required, the pressure of the surrounding outer atmosphere being sufficient. Outside of the house, or on the ground-floor (on the north side, if possible), should be a chamber heated by flues, hot air, steam, a suitable stove, or water pipes, and with one adjustable opening communicating with the outer fresh air, and another on the opposite side connected by a shaft or airway with the

hall of the ground-floor and the general staircase.

Each room to have an opening at its upper part communicating with the chimney, like an Arnott's ventilator, and capable of adjustment as regards area of aperture, and other openings of corresponding or excessive combined area leading from the hall or staircase to the lower part of the room. These may be covered with perforated zinc or wire gauze, so that the air may enter in a gentle, broken stream.

All the outer house-doors must be double, *i.e.*, with a porch or vestibule, and only one of each pair of doors opened at once. These should be well fitted, and the staircase air-tight. The kitchen to communicate with the rest of the house by similar double doors, and the kitchen fire to communicate directly with the upcast shaft or chimney by as small a stove-pipe as practicable. The kitchen fire will thus start the upcast and commence the draught of air from the warm chamber through the house toward the several openings into the shaft. In cold weather, this upcast action will be greatly re-enforced and maintained by the general warmth of all the air in the house, which itself will bodily become an upcast shaft immediately the inner temperature exceeds that of the air outside.

But the upcast of warm air can only take place by the admission of fresh air through the heating chamber, thence to hall and staircase, and thence onward through the rooms into the final shaft or chimney.

The openings into and out of the rooms being adjustable, they may be so regulated that each shall receive an equal share of fresh warm air; or, if desired, the bedroom chimney valves may be closed in the daytime, and thus the heat economized by being used only for the day rooms; or *vice versâ*, the communication between the upcast shaft and the lower rooms may be closed in the evening, and thus all the warm air be turned into the bedrooms at bedtime.

If the area of the entrance apertures of the rooms exceeds that of the outlet, only the latter need be adjusted; the room doors may, in fact, be left wide open without any possibility of "draught," beyond the ventilation current, which is limited by the dimension of the opening from the room into the shaft or chimney.

So far for winter time, when the ventilation problem is the easiest, because then the excess of inner warmth converts the whole house into an upcast shaft, and the whole outer atmosphere becomes a downcast. In the summer time, the kitchen fire would probably be insufficient to secure a sufficiently active upcast.

To help this there should be in one of the upper rooms—say an attic—an opening into the chimney secured by a small well-fitting door; and altogether enclosed within the chimney, a small automatic slow combustion stove (of which many were exhibited at South Kensington, that require feeding but once in twenty-four hours), or a large gas-burner. The heating-chamber below must now be converted into a cooling-chamber by an arrangement of wet cloths, presently to be described, so that all the air entering the house shall be reduced in temperature.

Or the winter course of ventilation may be reversed by building a special shaft connected with the kitchen fire, which, in this case, must not communicate with the house shaft. This special shaft may thus be made an upcast, and the rooms supplied with air from above down the house shaft, through the rooms, and out of the kitchen *viâ* the winter heating-chamber, which now has its communication with the outside air closed.

Reverting to the first-named method, which I think is better than the second, besides being less expensive, I must say a few concluding words on an important supplementary advantage which is obtainable wherever all the air entering the house passes through one opening, completely under control, like that of our

heating-chamber. The great evil of our town atmosphere is its dirtiness. In the winter it is polluted with soot particles; in the dry summer weather, the traffic and the wind stir up and mix with it particles of dust, having a composition that is better ignored, when we consider the quantity of horse-dung that is dried and pulverized on our roadways. All the dust that falls on our books and furniture was first suspended in the air we breathe inside our rooms. Can we get rid of any practically important portion of this?

I am able to answer this question, not merely on theoretical grounds, but as a result of practical experiments described in the following chapter, in which is reprinted a paper I read at the Society of Arts, March 19, 1879, recommending the enclosure of London backyards with a roofing of "wall canvas," or "paperhanger's canvas," so as to form cheap conservatories. This canvas, which costs about threepence per square yard, is a kind of coarse, strong, fluffy gauze, admitting light and air, but acting very effectively as an air filter, by catching and stopping the particles of soot and dust that are so fatal to urban vegetation.

I propose, therefore, that this well-tried device should be applied at the entrance aperture of our heating chamber, that the screens shall be well wetted in the summer, in order to obtain the cooling effect of evaporation, and in the winter shall be either wet or dry, as may be found desirable. The Parliament House experiments prove that they are good filters when wetted, and mine that they act similarly when dry.

By thus applying the principles of colliery ventilation to a specially-con structed house, we may, I believe, obtain a perfectly controllable indoor climate, with a range of variation not exceeding four or five degrees between the warmest and the coldest part of the house, or eight or nine degrees between summer and winter, and this may be combined with an abundant supply of fresh air everywhere, all filtered from the grosser portions of its irritant dust, which is positively poisonous to delicate lungs, and damaging to all. The cost of fuel would be far less than with existing arrangements, and the labor of attending to the one or two fires and the valves would also be less than that now required in the carrying of coal-scuttles, the removal of ashes, the cleaning of fireplaces, and the curtains and furniture they befoul by their escaping dust and smoke.

It is obvious that such a system of ventilation may even be applied to existing houses by mending the ill-fitting windows, shutting up the existing fire-holes, and using the chimneys as upcast shafts in the manner above described. This may be done in the winter, when the problem is easiest, and the demand for artificial climate the most urgent; but I question the possibility of summer ventilation and tempering of climate in anything short of a specially-built house or a materially altered existing dwelling. There are doubtless some exceptions to this, where the house happens to be specially suitable and easily adapted, but in ordinary houses we must be content with the ordinary devices of summer ventilation by doors and windows, plus the upper openings of the rooms into the chimneys expanded to their full capacity, and thus doing, even in summer, far better ventilating work than the existing fire-holes opening in the wrong place.

I thus expound my own scheme, not because I believe it to be perfect, but, on the contrary, as a suggestive project to be practically amended and adapted by others better able than myself to carry out the details. The feature that I think is novel and important, is that of consciously and avowedly applying to domestic ventilation the principles that have been so successfully carried out in the far more difficult problem of subterranean ventilation.

The dishonesty of the majority of the modern builders of suburban

"villa residences" is favorable to this and other similar radical household reforms, as thousands of these wretched tenements must sooner or later be pulled down, or will all come down together without any pulling the next time we experience one of those earthquake tremors which visit England about once in a century.

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# CONTENTS.

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